Smart cards

Contents

Chapter 1

Smart card

Contact-type smart cards may have many different contact pad layouts, such as these SIMs

Carte Vitale, the smart card used for health insurance in France

A **smart card**, **chip card**, or **integrated circuit card** (**ICC**) is any pocket-sized card with embedded integrated circuits. Smart cards are made of plastic, generally polyvinyl chloride, but sometimes polyethylene terephthalate based polyesters, acrylonitrile butadiene styrene or polycarbonate. Since April 2009, a Japanese company has manufactured reusable financial smart cards made from paper.[1]

Smart cards can provide identification, authentication, data storage and application processing.[2] Smart cards may provide strong security authentication for single sign-on (SSO) within large organizations.

1.1 History

1.1.1 Invention

In 1968 and 1969 German electrical engineers Helmut Gröttrup and Jürgen Dethloff jointly filed patents for the automated chip card (for details see page of Helmut Gröttrup). French inventor Roland Moreno[3] patented the memory card concept[4] in 1974. An important patent for smart cards with a microprocessor and memory as used today was filed by Jürgen Dethloff in 1976 and granted as USP 4105156 in 1978.[5] In 1977, Michel Ugon from Honeywell Bull invented the first microprocessor smart card. In 1978, Bull patented the SPOM (self-programmable one-chip microcomputer) that defines the necessary architecture to program the chip. Three years later, Motorola used this patent in its "CP8". At that time, Bull had 1,200 patents related to smart cards. In 2001, Bull sold its CP8 division together with its patents to Schlumberger, who subsequently combined its own internal smart card department and CP8 to create Axalto. In 2006, Axalto and Gemplus, at the time the world's top two smart card manufacturers, merged and became Gemalto. In 2008 Dexa Systems spun off from Schlumberger and acquired Enterprise Security Services business, which included the smart card solutions division responsible for deploying the first large scale public key infrastructure (PKI) based smart card management systems.

The first mass use of the cards was as a telephone card for payment in French pay phones, starting in 1983.

1.1.2 Carte Bleue

After the Télécarte, microchips were integrated into all French *Carte Bleue* debit cards in 1992. Customers inserted the card into the merchant's POS terminal, then typed the PIN, before the transaction was accepted. Only very limited transactions (such as paying small highway tolls) are processed without a PIN.

Smart-card-based "electronic purse" systems store funds on the card so that readers do not need network connectivity. They entered European service in the mid-1990s. They have been common in Germany (Geldkarte), Austria (Quick Wertkarte), Belgium (Proton), France (Moneo[6]), the Netherlands (Chipknip Chipper (decommissioned in 2001)), Switzerland ("Cash"), Norway ("Mondex"), Sweden ("Cash", decommissioned in 2004), Finland ("Avant"), UK ("Mondex"), Denmark ("Danmønt") and Portugal ("Porta-moedas Multibanco").

Since the 1990s, smart-cards have been the SIMs used in European GSM mobile phone equipment. Mobile phones are widely used in Europe, so smart cards have become very common.

1.1.3 EMV

For more details on this topic, see EMV.

EMV (*Europay MasterCard Visa*) compliant cards and equipment are widespread except in a few countries such as the United States. Typically, a country's national payment association, in coordination with MasterCard International, Visa International, American Express and JCB, jointly plan and implement EMV systems.

Historically, in 1993 several international payment companies agreed to develop smart-card specifications for debit and credit cards. The original brands were MasterCard, Visa, and Europay. The first version of the EMV system was released in 1994. In 1998 the specifications became stable.

EMVCo maintains these specifications. EMVco's purpose is to assure the various financial institutions and retailers that the specifications retain backward compatibility with the 1998 version. EMVco upgraded the specifications in 2000 and 2004.[7]

EMV compliant cards were accepted into the United States in 2014. MasterCard was the first company that has been allowed to use the technology in the United States. In addition, Chase Bank has also received a contract to use the technology on some of their newer credit card plans. The United States has felt pushed to use the technology because of the increase in identity theft. The credit card information stolen from Target in late 2013 was one of the largest indicators that it American credit card information is not safe. Target has made the decision on April 30th, 2014 that they are going to try and implement the smart chip technology in order to protect themselves from future credit card identity theft.

Before 2014, the general consensus in America was that there was enough security measures to avoid credit card theft and that the smart chip was not necessary. The cost of the smart chip technology is excessive, which is why most of the corporations do not want to pay for it in the United States. The debate will come when it online credit theft insecure enough for the United States to invest in the technology. A pro to switching to the smart chip technology is that when trying to purchase internationally using credit cards, having the smart chip will make it easier because everyone else has already implemented the technology.

1.1.4 Development of contactless systems

Contactless smart cards do not require physical contact between a card and reader. They are becoming more popular for payment and ticketing. Typical uses include mass transit and motorway tolls. Visa and MasterCard implemented a version deployed in 2004–2006 in the U.S. Most contactless fare collection systems are incompatible, though the MIFARE Standard card from NXP Semiconductors has a considerable market share in the US and Europe.

Smart cards are also being introduced for identification and entitlement by regional, national, and international organizations. These uses include citizen cards, drivers' licenses, and patient cards. In Malaysia, the compulsory national ID MyKad enables eight applications and has 18 million users. Contactless smart cards are part of ICAO biometric passports to enhance security for international travel.

1.2 Design

A smart card may have the following generic characteristics:

- Dimensions similar to those of a credit card. ID-1 of the ISO/IEC 7810 standard defines cards as nominally 85.60 by 53.98 millimetres (3.370 in × 2.125 in). Another popular size is ID-000 which is nominally 25 by 15 millimetres (0.984 in × 0.591 in) (commonly used in SIM cards). Both are 0.76 millimetres (0.030 in) thick.
- Contains a tamper-resistant security system (for example a secure cryptoprocessor and a secure file system) and provides security services (e.g., protects in-memory information).
- Managed by an administration system which securely interchanges information and configuration

settings with the card, controlling card blacklisting and application-data updates.

- Communicates with external services via card-reading devices, such as ticket readers, ATMs, DIP reader, etc.

1.2.1 Contact smart cards

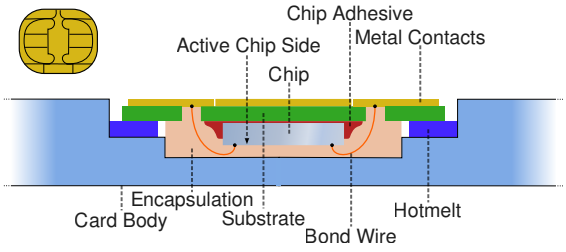


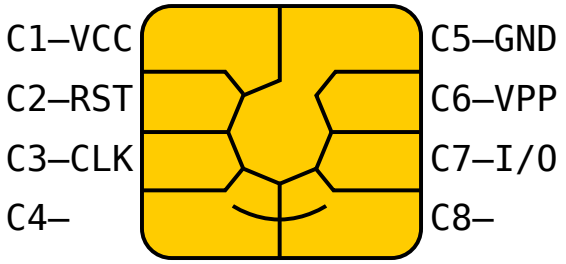
Illustration of smart card structure and packaging

Smart card reader on a laptop

Contact smart cards have a contact area of approximately 1 square centimetre (0.16 sq in), comprising several gold-plated contact pads. These pads provide electrical connectivity when inserted into a reader,[9] which is used as a communications medium between the smart card and a host (e.g., a computer, a point of sale terminal) or a mobile telephone. Cards do not contain batteries; power is supplied by the card reader.

The ISO/IEC 7810 and ISO/IEC 7816 series of standards define:

- physical shape and characteristics
- electrical connector positions and shapes
- electrical characteristics
- communications protocols, including commands sent to and responses from the card
- basic functionality



*A smart card pinout. **VCC**: Power supply. **RST**: Reset signal, used to reset the card's communications. **CLK**: Provides the card with a clock signal, from which data communications timing is derived. **GND**: Ground (reference voltage). **VPP**: ISO/IEC 7816-3:1997 designated this as a programming voltage: an input for a higher voltage to program persistent memory (e.g., EEPROM). ISO/IEC 7816-3:2006 designates it SPU, for either standard or proprietary use, as input and/or output. **I/O**: Serial input and output (half-duplex). **C4, C8**: The two remaining contacts are AUX1 and AUX2 respectively, and used for USB interfaces and other uses.[8] However, the usage defined in ISO/IEC 7816-2:1999/Amd 1:2004 may have been superseded by ISO/IEC 7816-2:2007.*

Because the chips in financial cards are the same as those used in subscriber identity modules (SIMs) in mobile phones, programmed differently and embedded in a different piece of PVC, chip manufacturers are building to the more demanding GSM/3G standards. So, for example, although the EMV standard allows a chip card to draw 50 mA from its terminal, cards are normally well below the telephone industry's 6 mA limit. This allows smaller and cheaper financial card terminals.

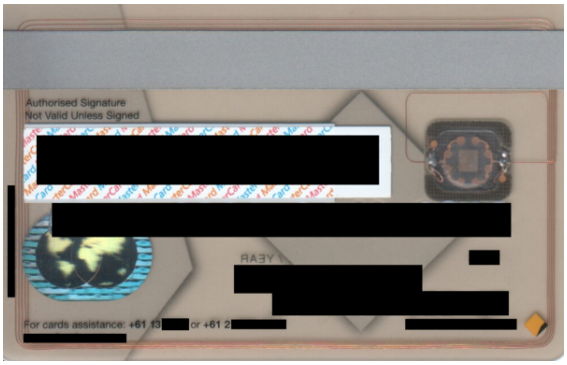
Communication protocols for contact smart cards include T=0 (character-level transmission protocol, defined in ISO/IEC 7816-3) and T=1 (block-level transmission protocol, defined in ISO/IEC 7816-3).

1.2.2 Contactless smart cards

Main article: Contactless smart card

A second card type is the *contactless smart card*, in which the card communicates with and is powered by the reader through RF induction technology (at data rates of 106–848 kbit/s). These cards require only proximity to an antenna to communicate. Like smart cards with contacts, contactless cards do not have an internal power source. Instead, they use an inductor to capture some of the incident radio-frequency interrogation signal, rectify it, and use it to power the card's electronics.

APDU transmission via a contactless interface is defined in ISO/IEC 14443−4.



A hybrid smart card which clearly shows the antenna connected to the main chip

1.2.3 Hybrids

Dual-interface cards implement contactless and contact interfaces on a single card with some shared storage and processing. An example is Porto's multi-application transport card, called Andante, which uses a chip with both contact and contactless (ISO/IEC 14443 Type B) interfaces.

1.3 Applications

1.3.1 Financial

Smart cards serve as credit or ATM cards, fuel cards, mobile phone SIMs, authorization cards for pay television, household utility pre-payment cards, high-security identification and access-control cards, and public transport and public phone payment cards.

Smart cards may also be used as electronic wallets. The smart card chip can be "loaded" with funds to pay parking meters, vending machines or merchants. Cryptographic protocols protect the exchange of money between the smart card and the machine. No connection to a bank is needed. The holder of the card may use it even if not the owner. Examples are Proton, Geldkarte, Chipknip and Moneo. The German Geldkarte is also used to validate customer age at vending machines for cigarettes.

Main articles: Contactless smart card and Credit card

These are the best known payment cards (classic plastic card):

- Visa: Visa Contactless, Quick VSDC, "qVSDC", Visa Wave, MSD, payWave
- MasterCard: PayPass Magstripe, PayPass MChip
- American Express: ExpressPay
- Discover: Zip

Roll-outs started in 2005 in the U.S. Asia and Europe followed in 2006. Contactless (non-PIN) transactions cover a payment range of ~$5–50. There is an ISO/IEC 14443 PayPass implementation. Some, but not all PayPass implementations conform to EMV.

Non-EMV cards work like magnetic stripe cards. This is common in the U.S. (PayPass Magstripe and VISA MSD). The cards do not hold or maintain the account balance. All payment passes without a PIN, usually in off-line mode. The security of such a transaction is no greater than with a magnetic stripe card transaction.

EMV cards can have either contact or contactless interfaces. They work as if they were a normal EMV card with a contact interface. Via the contactless interface they work somewhat differently, in that the card commands enabled improved features such as lower power and shorter transaction times.

1.3.2 SIM

The subscriber identity modules used in mobile-phone systems are reduced-size smart cards, using otherwise identical technologies.

1.3.3 Identification

Smart-cards can authenticate identity. Usually, they employ a public key infrastructure (PKI). The card stores an encrypted digital certificate issued from the PKI provider along with other relevant information. Examples include the U.S. Department of Defense (DoD) Common Access Card (CAC), and other cards used by other governments for their citizens. If they include biometric identification data, cards can provide superior two- or three-factor authentication.

Smart cards are not always privacy-enhancing, because the subject may carry incriminating information on the card. Contactless smart cards that can be read from within a wallet or even a garment simplify authentication; however, criminals may access data from these cards.

Cryptographic smart cards are often used for single sign-on. Most advanced smart cards include specialized cryptographic hardware that uses algorithms such as RSA and DSA. Today's cryptographic smart cards generate key pairs on board, to avoid the risk from having more than one copy of the key (since by design there usually isn't a way to extract private keys from a smart card). Such smart cards are mainly used for digital signatures and secure identification.

The most common way to access cryptographic smart card functions on a computer is to use a vendor-provided PKCS#11 library. On Microsoft Windows the CSP API is also supported.

The most widely used cryptographic algorithms in smart

cards (excluding the GSM so-called "crypto algorithm") are Triple DES and RSA. The key set is usually loaded (DES) or generated (RSA) on the card at the personalization stage.

Some of these smart cards are also made to support the NIST standard for Personal Identity Verification, FIPS 201.

Turkey implemented the first smart card driver's license system in 1987. Turkey had a high level of road accidents and decided to develop and use digital tachograph devices on heavy vehicles, instead of the existing mechanical ones, to reduce speed violations. Since 1987, the professional driver's licenses in Turkey have been issued as smart cards. A professional driver is required to insert his driver's license into a digital tachograph before starting to drive. The tachograph unit records speed violations for each driver and gives a printed report. The driving hours for each driver are also being monitored and reported. In 1990 the European Union conducted a feasibility study through BEVAC Consulting Engineers, titled "Feasibility study with respect to a European electronic drivers license (based on a smart-card) on behalf of Directorate General VII". In this study, chapter seven describes Turkey's experience.

Argentina's Mendoza province began using smart card driver's licenses in 1995. Mendoza also had a high level of road accidents, driving offenses, and a poor record of recovering fines. Smart licenses hold up-to-date records of driving offenses and unpaid fines. They also store personal information, license type and number, and a photograph. Emergency medical information such as blood type, allergies, and biometrics (fingerprints) can be stored on the chip if the card holder wishes. The Argentina government anticipates that this system will help to collect more than $10 million per year in fines.

In 1999 Gujarat was the first Indian state to introduce a smart card license system.[10] As of 2005, it has issued 5 million smart card driving licenses to its people.[11]

In 2002, the Estonian government started to issue smart cards named ID Kaart as primary identification for citizens to replace the usual passport in domestic and EU use. As of 2010 about 1 million smart cards have been issued (total population is about 1.3 million) and they are widely used in internet banking, buying public transport tickets, authorization on various websites etc.

By the start of 2009 the entire population of Spain and Belgium will have an eID card that is used for identification. These cards contain two certificates: one for authentication and one for signature. This signature is legally enforceable. More and more services in these countries use eID for authorization.[12][13]

After August 14, 2012, the ID card of Pakistan will be replaced. The Smart Card is a third generation chip-based identity document that is produced according to international standards and requirements. The card has over 36 physical security features and has the latest encryption codes. This smart card will also replace the NICOP (the ID card for overseas Pakistani).

Smart cards may identify emergency responders and their skills. Cards like these allow first responders to bypass organizational paperwork and focus more time on the emergency resolution. In 2004, The Smart Card Alliance expressed the needs: "to enhance security, increase government efficiency, reduce identity fraud, and protect personal privacy by establishing a mandatory, Government-wide standard for secure and reliable forms of identification".[14] emergency response personnel can carry these cards to be positively identified in emergency situations. WidePoint Corporation, a smart card provider to FEMA, produces cards that contain additional personal information, such as medical records and skill sets.

In 2007, the Open Mobile Alliance (OMA) proposed a new standard defining V1.0 of the Smart Card Web Server (SCWS), an HTTP server embedded in a SIM card intended for a smartphone user.[15] The non-profit trade association SIMalliance has been promoting the development and adoption of SCWS. SIMalliance states that SCWS offers end-users a familiar, OS-independent, browser-based interface to secure, personal SIM data. As of mid-2010, SIMalliance had not reported widespread industry acceptance of SCWS.[16] The OMA has been maintaining the standard, approving V1.1 of the standard in May 2009, and V1.2 is expected to be approved in October 2012.[17]

1.3.4 Public transit

Main article: List of smart cards

Smart cards and integrated ticketing are used by many public transit operators. Card users may also make small purchases using the cards. Some operators offer points for usage, exchanged at retailers or for other benefits.[18] Examples include Los Angeles's TAP card, Singapore's CEPAS, Hong Kong's Octopus Card, London's Oyster Card, Dublin's Leap card, Brussels' MoBIB, Québec's OPUS card, San Francisco's Clipper card, Auckland's AT Hop, Brisbane's go card and Sydney's Opal card. However, these present a privacy risk because they allow the mass transit operator (and the government) to track an individual's movement. In Finland, for example, the Data Protection Ombudsman prohibited the transport operator Helsinki Metropolitan Area Council (YTV) from collecting such information, despite YTV's argument that the card owner has the right to a list of trips paid with the card. Earlier, such information was used in the investigation of the Myyrmanni bombing.

The UK's Department for Transport mandated smart cards to administer travel entitlements for elderly and disabled residents. These schemes let residents use the cards for more than just bus passes. They can also be used for

taxi and other concessionary transport. One example is the "Smartcare go" scheme provided by Ecebs.[19] The UK systems use the ITSO_Ltd specification.

1.3.5 Computer security

Smart cards can be used as a security token.

The Mozilla Firefox web browser can use smart cards to store certificates for use in secure web browsing.[20]

Some disk encryption systems, such as Microsoft's BitLocker, can use smart cards to securely hold encryption keys, and also to add another layer of encryption to critical parts of the secured disk.

GnuPG, the well known encryption suite, also supports storing keys in a smart card.[21]

Smart cards are also used for single sign-on to log on to computers.

1.3.6 Schools

Smart cards are being provided to students at schools and colleges.[22][23][24] Uses include:

- Tracking student attendance
- As an electronic purse, to pay for items at canteens, vending machines, laundry facilities, etc...
- Tracking and monitoring food choices at the canteen, to help the student maintain a healthy diet
- Tracking loans from the school library
- Access control for admittance to restricted buildings, dormitories, and other facilities. This requirement may be enforced at all times (such as for a laboratory containing valuable equipment), or just during after-hours periods (such as for an academic building that is open during class times, but restricted to authorized personnel at night), depending on security needs.
- Access to transportation services

1.3.7 Healthcare

Smart health cards can improve the security and privacy of patient information, provide a secure carrier for portable medical records, reduce health care fraud, support new processes for portable medical records, provide secure access to emergency medical information, enable compliance with government initiatives (e.g., organ donation) and mandates, and provide the platform to implement other applications as needed by the health care organization.[25]

1.3.8 Other uses

Smart cards are widely used to protect digital television streams. VideoGuard is a specific example of how smart card security worked.

1.3.9 Multiple-use systems

The Malaysian government promotes MyKad as a single system for all smart-card applications. MyKad started as identity cards carried by all citizens and resident non-citizens. Available applications now include identity, travel documents, drivers license, health information, an electronic wallet, ATM bank-card, public toll-road and transit payments, and public key encryption infrastructure. The personal information inside the MYKAD card can be read using special APDU commands.[26]

1.4 Security

Main article: Smart card security

Smart cards have been advertised as suitable for personal identification tasks, because they are engineered to be tamper resistant. The chip usually implements some cryptographic algorithm. There are, however, several methods for recovering some of the algorithm's internal state.

Differential power analysis involves measuring the precise time and electrical current required for certain encryption or decryption operations. This can deduce the on-chip private key used by public key algorithms such as RSA. Some implementations of symmetric ciphers can be vulnerable to timing or power attacks as well.

Smart cards can be physically disassembled by using acid, abrasives, or some other technique to obtain unrestricted access to the on-board microprocessor. Although such techniques obviously involve a fairly high risk of permanent damage to the chip, they permit much more detailed information (e.g. photomicrographs of encryption hardware) to be extracted.

1.5 Benefits

The benefits of smart cards are directly related to the volume of information and applications that are programmed for use on a card. A single contact/contactless smart card can be programmed with multiple banking credentials, medical entitlement, driver's license/public transport entitlement, loyalty programs and club memberships to name just a few. Multi-factor and proximity authentication can and has been embedded into smart cards to increase the security of all services on the card.

For example, a smart card can be programmed to only allow a contactless transaction if it is also within range of another device like a uniquely paired mobile phone. This can significantly increase the security of the smart card.

Governments and regional authorities save money because of improved security, better data and reduced processing costs. These savings help reduce public budgets or enhance public services. There are many examples in the UK, many using a common open LASSeO specification.[27]

Individuals have better security and more convenience with using smart cards that perform multiple services. For example, they only need to replace one card if their wallet is lost or stolen. The data storage on a card can reduce duplication, and even provide emergency medical information.

1.6 Problems

The plastic card in which the chip is embedded is fairly flexible. The larger the chip, the higher the probability that normal use could damage it. Cards are often carried in wallets or pockets, a harsh environment for a chip. However, for large banking systems, failure-management costs can be more than offset by fraud reduction.

If the account holder's computer hosts malware, the smart card security model may be broken. Malware can override the communication (both input via keyboard and output via application screen) between the user and the application. Man-in-the-browser malware (e.g. the trojan Silentbanker) could modify a transaction, unnoticed by the user. Banks like Fortis and Belfius in Belgium and Rabobank ("random reader") in the Netherlands combine a smart card with an unconnected card reader to avoid this problem. The customer enters a challenge received from the bank's website, a PIN and the transaction amount into the reader, The reader returns an 8-digit signature. This signature is manually entered into the personal computer and verified by the bank, preventing malware from changing the transaction amount.

Smart cards have also been the targets of security attacks. These attacks range from physical invasion of the card's electronics, to non-invasive attacks that exploit weaknesses in the card's software or hardware. The usual goal is to expose private encryption keys and then read and manipulate secure data such as funds. Once an attacker develops a non-invasive attack for a particular smart card model, he is typically able to perform the attack on other cards of that model in seconds, often using equipment that can be disguised as a normal smart card reader.[28] While manufacturers may develop new card models with additional security, it may be costly or inconvenient for users to upgrade vulnerable systems. Tamper-evident and audit features in a smart card system help manage the risks of compromised cards.

Another problem is the lack of standards for functionality and security. To address this problem, The Berlin Group launched the ERIDANE Project to propose "a new functional and security framework for smart-card based Point of Interaction (POI) equipment".[29]

1.7 See also

- Access badge
- ATM card
  - Debit card
- BasicCard
- Credit card
- Keycard lock
- List of smart cards
- Proximity card
- Transit pass
- Travel card

Other

- Access control
- Biometric passport
- Card printer
- Electronic money
- GlobalPlatform
- Identity document
- Java Card
- MULTOS
- Open Smart Card Development Platform
- Payment Card Industry Data Security Standard
- Radio-frequency identification
- Self-service
- Security engineering
- SNAPI

1.8 Further reading

- Rankl, W.; W. Effing (1997). *Smart Card Handbook*. John Wiley & Sons. ISBN 0-471-96720-3.
- Guthery, Scott B.; Timothy M. Jurgensen (1998). *SmartCard Developer's Kit*. Macmillan Technical Publishing. ISBN 1-57870-027-2.

1.9 References

[1] "development of the "KAMICARD" IC card made from recyclable and biodegradable paper". Toppan Printing Company. Archived from the original on 2009-02-27. Retrieved 2009-03-27.

[2] *Multi-application Smart Cards*. Cambridge University Press.

[3] http://si-pwebsrch02.si.edu/search?site=americanhistory&client=americanhistory&proxystylesheet=americanhistory&output=xml_no_dtd&filter=0&q=roland+moreno&submit.x=13&submit.y=8&s=SS

[4] "Monticello Memoirs Program". Computerworld honors. Retrieved 13 February 2012.

[5] "Espacenet - Original document". Worldwide.espacenet.com. 1978-08-08. Retrieved 2014-02-13.

[6] Moneo's website (in French)

[7] EMVco

[8] ISO/IEC 7816-2:1999/Amd 1:2004 *Assignment of contacts C4 and C8*

[9] *Smart Cards: More or 'Less'*. ABI/INFORM Global database.

[10] Smart Card License System

[11] "Smart Card Driving License System in Gujarat"

[12] "Portal Oficial sobre el DNI electrónico:". Dnielectronico.es. Retrieved 2014-02-13.

[13] "Taalkeuze/Choix de langue fedict.belgium.be". Eid.belgium.be. Retrieved 2014-02-13.

[14] "Emergency Response Official Credentials: An Approach to Attain Trust in Credentials across Multiple Jurisdictions for Disaster Response and Recovery". January 3, 2011.

[15] "OMA Newsletter 2007 Volume 2". Retrieved March 20, 2012.

[16] Martin, Christophe (30 June 2010). "Update from SIMalliance on SCWS". Retrieved March 20, 2012.

[17] "OMA Smart Card Web Server (SCWS)". Retrieved March 20, 2012.

[18] Octopus Card Benefits

[19] "Smartcare go". Retrieved 24 September 2012.

[20] Mozilla certificate store

[21] smartcard howto for GNUPG

[22] Varghese, Sam (2004-12-06). "Qld schools benefit from smart cards". *The Age*.

[23] CreditCards.com (2009-10-27). "Cashless lunches come to Australian schools". Australia.creditcards.com. Retrieved 2014-02-13.

[24] "News Release - Smart card technology to monitor smart food choices in schools". Ifr.ac.uk. 2005-07-14. Retrieved 2014-02-13.

[25] Smartcardalliance.org

[26] MYKAD SDK

[27] Lasseo#Examples of Smart Card Schemes using LASSeO

[28] Bar-El, Hagai. "Known Attacks Against Smartcards". Discretix Technologies Ltd. Retrieved February 20, 2013.

[29] "Related Initiatives". *Home web for The Berlin Group*. The Berlin Group. 2005-08-01. Retrieved 2007-12-20.

1.10 External links

- Smart card at DMOZ

Chapter 2

Oyster card

The **Oyster card** is a form of electronic ticketing used on public transport in Greater London in the United Kingdom. It is promoted by Transport for London and is valid on travel modes across London including London Underground, London Buses, the Docklands Light Railway (DLR), London Overground, trams, some river boat services, and most National Rail services within the London fare zones.

A standard Oyster card is a blue credit-card-sized stored-value contactless smartcard that can hold single tickets, period tickets and travel permits, which must be added to the card before travel. Passengers touch it on an electronic reader when entering and leaving the transport system in order to validate it or deduct funds. Cards may be "topped-up" by recurring payment authority, by online purchase, at credit card terminals or by cash, the last two methods at stations or ticket offices. The card is designed to reduce the number of transactions at ticket offices and the number of paper tickets. Usage is encouraged by offering substantially cheaper fares than with cash[2] though the acceptance of cash is being phased out. On London buses, cash is no longer accepted.

The card was first issued to the public in July 2003 with a limited range of features and there continues to be a phased introduction of further functions. By June 2012, over 43 million Oyster cards had been issued and more than 80% of all journeys on public transport in London were made using the card.[3]

As part of TfL's 'Future Ticketing Programme' the Oyster card platform is due to be replaced by a contactless payment card system by June 2015.[4]

2.1 Background

2.1.1 Operator

The Oyster card was set up under a Private Finance Initiative (PFI) contract between TfL and TranSys, a consortium of suppliers that included EDS and Cubic Transportation Systems (responsible for day-to-day management) and Fujitsu and WS Atkins (shareholders with no active involvement).[5] The £100 million contract was signed in 1998 for a term of 17 years until 2015 at a total cost of £1.1 billion.[6]

In August 2008, TfL decided to exercise a break option in the contract to terminate it in 2010, five years early. This followed a number of technical failures.[7] TfL stated that the contractual break was to reduce costs, not connected to the system failures.[8] In November 2008 a new contract was announced between TfL and Cubic and EDS for two of the original consortium shareholders to run the system from 2010 until 2013.[9]

2.1.2 Brand

The Oyster name was agreed on after a lengthy period of research managed by TranSys and agreed by TfL. Several names were considered, and Oyster was chosen as a fresh approach that was not directly linked to transport, ticketing or London. According to Andrew McCrum, now of Appella brand name consultants, who was brought in to find a name by Saatchi and Saatchi Design (contracted by TranSys), Oyster was conceived and promoted because of the metaphorical implications of security and value in the component meanings of the hard bivalve shell and the concealed pearl, the association of London and the River Thames with oysters, and the well-known travel-related idiom "the world is your oyster".

The intellectual property rights to the Oyster brand originally belonged to Transys. Following the renegotiation of the operating contract in 2008, TfL sought to retain the right to use the Oyster brand after the termination of its partnership with Transys,[9][10] eventually acquiring the rights to the brand in 2010 at a cost of £1 million.[11]

2.1.3 Technology

The Oyster card has a claimed proximity range of about 80 mm (3 inches). The card operates as a RFID system and is compatible with ISO/IEC 14443 types A and B. Oyster readers can also read other types of cards including Cubic Go-Cards. From its inception until January 2010, Oyster cards were based on NXP/Philips' MIFARE Classic 1k chips provided by Giesecke & Devrient, Gemalto and SchlumbergerSema.[12] Since De-

A damaged card, revealing the microchip in the lower right corner and the aerial running around the edge of the card.

cember 2009 all new Oyster cards use MIFARE DESFire EV1 chips. From February 2010 MIFARE Classic-based Oyster cards were no longer issued.[13] MIFARE DESFire cards are now widely used as transport smartcards.

MIFARE Classic chips, on which the original Oyster card was based, are hard-wired logic smartcards, meaning that they have limited computing power designed for a specific task. The MIFARE DESFire chips used on the new Oyster card are CPUs with much more sophisticated security features and more complex computation power. They are activated only when they are in an electromagnetic field compatible with ISO/IEC 14443 type A, provided by Oyster readers. The readers read information from the cards, calculate whether to allow travel, assess any fare payable and write back information to the card. Some basic information about the MIFARE Classic or MIFARE DESFire chip can be read by any ISO/IEC 14443 type A compatible reader, but Oyster-specific information cannot be read without access to the encryption used for the Oyster system. While it has been suggested that a good reader could read personal details from a distance, there has been no evidence of anyone being able to decrypt Oyster information. By design the cards do not carry any personal information. Aluminium shielding has been suggested to prevent any personal data from being read.[14]

Oyster uses a distributed settlement framework. All transactions are settled between the card and reader alone. Readers transmit the transactions to the back office in batches but there is no need for this to be done in real time. The back office acts mainly as a record of transactions that have been completed between cards and readers. This provides a high degree of resilience.

In 2008 a fashion caught on for removing the RFID chip from Oyster cards and attaching it to wrist watches and bracelets. This allowed commuters to pass through the gates by "swiping" their hand without the need to take out a proper card. Although the RFID chips were charged in the normal way and no fare evasion was involved, TfL disapproved of the practice and threatened to fine anyone not carrying a full undamaged card,[15] though it is not clear what the actual offence would be.

2.1.4 Architecture

The Oyster system is based on a closed, proprietary architecture from Cubic Transportation Systems. The card readers were developed entirely by Cubic, whereas development of the back office systems was started by Fujitsu and completed by Cubic. The system has the capability to interface with equipment or services provided by other suppliers. The Oyster website is not part of the closed system but interfaces with it. Similarly, Oyster readers are now embedded into ticket machines produced by Shere and Scheidt and Bachmann on the national rail network.

In early 2007, TfL and Deloitte worked to migrate the online payment systems to a more open architecture, using a number of open source components such as Linux, to resolve issues of lock-in costs, updates, incorporation of new security standards of PCI DSS, non-scalability, low and inconsistent quality of service, and slower response time to business changes.[16]

2.2 Features

2.2.1 Registration and protection

Oyster cards can be registered or protected for loss or theft. Full registration can be done at a London Underground station, an Oyster Ticket Stop (shop) or a Travel Information Centre: an Oyster registration form must be filled in (either at time of purchase or subsequently). Registration enables the customer to buy any product for the card and to have an after-sales service, and it protects against theft or loss. The customer has to supply a Security Answer: either their mother's maiden name, memorable date or memorable place. All adult Oyster cards purchased online or by phone are fully registered. (This does not include Visitor Oyster cards.)

Oyster cards obtained at stations or shops cannot be fully registered online. However, cards can be *protected* online by setting up an Oyster online account and linking the card to that account. This allows for a full protection against theft or loss, but the Oyster card will be able to hold only 7-day season tickets and/or pay-as-you-go.[17]

2.2.2 Sales

Oyster cards can be purchased from a number of different outlets in the London area:

- London Underground or London Overground ticket windows
- ticket machines at London Underground stations, which accept banknotes, coins, and credit and debit cards.

Oyster card vending machine, installed at London Bridge station in December 2006. All machines of this design have been phased out.

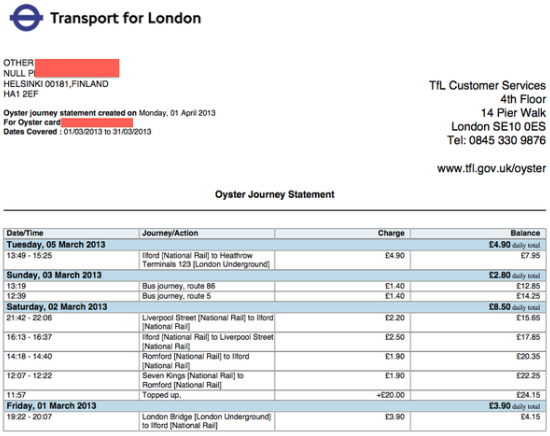
- about 4,000 Oyster Ticket Stop agents (usually newsagent's shops)
- selected National Rail stations, some of which are also served by London Underground
- Travel Information Centres
- online via the TfL website
- by telephone sales from TfL.[18]

Visitor Oyster cards can be obtained from Visit Britain outlets around the world, and from other transport operators, such as EasyJet and Gatwick Express as well as online and from any ticket office. However, these limited-functionality cards cannot be registered. A £5 deposit is required which will be refunded in cash upon return of the card. Any remaining credit on the card is refundable as well.[19]

The cards were originally free, but a refundable deposit of £3 was subsequently introduced,[20] increased to £5 in January 2011.[21] The deposit is refunded only on surrender of the card to TfL, primarily to a London Underground station. TfL said this was due to the administrative and environmental costs of customers disposing of Oyster cards instead of re-using them. A registration form can be obtained at or after the time of purchase, which if not completed restricts the Oyster card to Pay-as-you-go and weekly tickets.

Ticket vending machines on most National Rail stations will top-up Oyster cards and sell tickets that can be loaded on to Oyster. New Oyster cards are not available at most National Rail stations and termini.[22] At several main line termini, TfL runs Travel Information Centres, which do sell Oyster.

2.2.3 Reporting


Transport for London

OTHER
NULL P[redacted]
HELSINKI 00181,FINLAND
HA1 2EF

Oyster journey statement created on Monday, 01 April 2013
For Oyster card [redacted]
Dates Covered : 01/03/2013 to 31/03/2013

TfL Customer Services
4th Floor
14 Pier Walk
London SE10 0ES
Tel: 0845 330 9876

www.tfl.gov.uk/oyster

Oyster Journey Statement

Date/Time	Journey/Action	Charge	Balance
Tuesday, 05 March 2013			**£4.90** daily total
13:49 - 15:25	Ilford [National Rail] to Heathrow Terminals 123 [London Underground]	£4.90	£7.95
Sunday, 03 March 2013			**£2.80** daily total
13:19	Bus journey, route 86	£1.40	£12.85
12:39	Bus journey, route 5	£1.40	£14.25
Saturday, 02 March 2013			**£8.50** daily total
21:42 - 22:06	Liverpool Street [National Rail] to Ilford [National Rail]	£2.20	£15.65
16:13 - 16:37	Ilford [National Rail] to Liverpool Street [National Rail]	£2.50	£17.85
14:18 - 14:40	Romford [National Rail] to Ilford [National Rail]	£1.90	£20.35
12:07 - 12:22	Seven Kings [National Rail] to Romford [National Rail]	£1.90	£22.25
11:57	Topped up.	+£20.00	£24.15
Friday, 01 March 2013			**£3.90** daily total
19:22 - 20:07	London Bridge [London Underground] to Ilford [National Rail]	£3.90	£4.15

Oyster Travel Statement

Touch-screen ticket machines report the last eight journeys and last top-up amount. The same information is available as a print-out from ticket offices, and also on board London Buses by request. The balance is displayed on some Underground barriers at the end of journeys that have caused a debit from the balance, and can also be requested at newsagents and National Rail stations that provide a top-up facility.

Oyster Online service can also deliver regular Travel Statements via email.

A complete 8-week 'touch' history can be requested from TfL: for registered and protected Oyster cards, TfL can provide the history for the previous 8 weeks, but no further back. Oyster online also displays up to 8 weeks of journey history but will not show any transactions that occurred before the Oyster card was linked to the account.

2.3 Use

2.3.1 Touching in and out

Travellers touch the card on a distinctive yellow circular reader (a Cubic Tri-Reader) on the automated barriers at London Underground stations to 'touch in' and 'touch out' at the start and end of a journey (contact is not necessary, but the range of the reader is only a few mm). Tram stops and buses also have readers on the driver/conductor's ticket machine, and on these modes

Oyster card readers on London Underground ticket barriers at Canary Wharf.

passengers must touch their card to the reader at the start of their journey only. Most DLR stations and occasionally London Underground stations as at Waterloo do not have automatic barriers, so passengers must remember to check both in and out, but such a step is not needed if transferring between modes within a station.

Oyster cards can be used to store both period travelcards and bus passes (of one week or more), and a Pay-as-you-go balance.

2.3.2 Season tickets

Main article: Travelcard

An Oyster card can hold up to three season tickets at the same time. Season tickets are Bus & Tram Passes or Travelcards lasting 7 days, 1-month, or any duration up to one year (annual).

There is no essential difference in validity or cost between a 7-day, monthly or longer period Travelcard on Oyster and one on a traditional paper ticket; they are valid on all Underground, Overground, DLR, bus, tram and national rail services within the zones purchased. See the main article for a fuller explanation of Travelcards. Tube, DLR and London Overground Travelcards may be used on buses in all zones. Trams may also be used if the travelcard includes Zones 3, 4, 5 or 6.[23]

Although TfL asks all Oyster users to swipe their card at entry/exit points of their journey, in practice Travelcard holders only need to "touch in" and "touch out" to operate ticket barriers or because they intend to travel outside the zones for which their Travelcard is valid. As long as the Travelcard holder stays within their permitted zones no fare will be deducted from the pay as you go funds on the card. The Oyster system checks that the Travelcard is valid in the zones it is being used in.

Travel outside zones

If users travel outside the valid zones of their Travelcard (but within Oyster payment zones), any remaining fare due may be deducted from their pay-as-you-go funds (see below for how this is calculated). From 22 May 2011 *Oyster Extension Permits* (OEPs) were no longer required.[24] Before that date, users who travelled outside the zones of their Travelcard, and whose journey involved the use of a National Rail service, were required to set an OEP on their Oyster card before travelling, to ensure that they paid for the extra-zonal journey.

Renewals

Oyster card top-up machine at Emirates Royal Docks

Oyster card Travelcards can be renewed at the normal sales points and ticket machines at London Underground or London Overground stations, Oyster Ticket Stop agents, or some National Rail stations. Travelcards can also be renewed online via the Oystercard website, or by telephone sales from TfL; users must then nominate a Tube or overground station where they will swipe their card in order to charge up the card with the funds or season ticket purchased. Alternatively a user can choose to automatically add either £20 or £40 every time the balance on the card falls below £10. There are further restrictions on when an online purchase can be "collected" by swiping in at a station, after the date of online purchase (Travelcard: up to five days before start date until two days after the start date; pay as you go: from the day after order is placed for a total of 8 days).[25] If the fare

is purchased online before 23:00, it will be available the following day. For more Travelcard renewal information, see the section on Recharging in this article. Travelcard renewals cannot be added from a reader on a bus.

2.3.3 Pay-as-you-go

In addition to holding Travelcards and bus passes, Oyster cards can also be used as stored-value cards, holding electronic funds of money. Amounts are deducted from the card each time it is used, and the funds can be "recharged" when required. The maximum value that an Oyster card may hold is £90. This system is known as "pay as you go" (abbreviated PAYG), because instead of holding a season ticket, the user only pays at the point of use.

When Oyster cards were introduced, the PAYG system was initially named "pre pay", and this name is still sometimes used by National Rail. TfL officially refers to the system as "pay as you go" in all publicity.

The validity of PAYG has a more complex history as it has only been gradually accepted by transport operators independent of TfL. Additionally, the use of PAYG differs across the various modes of transport in London, and passengers are sometimes required to follow different procedures to pay for their journey correctly.

It is possible to have a negative pay-as-you-go balance after completing a journey, but this will prevent the card from being used (even if it is loaded with a valid Travelcard) until the card is topped up.

Oyster route validators

In 2009, TfL introduced a new type of Oyster card validator, distinguished from the standard yellow validators by having a pink-coloured reader. They do not deduct funds, but are used at peripheral interchange points to confirm journey details. Oyster Pay-As-You-Go users travelling between two points without passing through Zone 1 are eligible for a lower fare, and from 6 September 2009 can confirm their route by touching their Oyster cards on the pink validators when they change trains, allowing them to be charged the appropriate fare without paying for Zone 1 travel. The pink validators are currently located at 15 interchange stations.

- Gospel Oak
- Gunnersbury
- Highbury & Islington
- Kensington Olympia
- Rayners Lane
- Stratford
- West Brompton
- Willesden Junction
- Blackhorse Road
- Wimbledon
- Richmond
- Whitechapel
- Canada Water
- Surrey Quays (introduced September 2013)
- Clapham Junction (introduced September 2013)

An example journey would be Watford Junction to Richmond, which as of May 2010 costs £7.30 peak and £4.80 off-peak when travelling via Zone 1. If travelling on a route outside Zone 1 via Willesden Junction, the fares are £3.50 and £1.30 respectively, which can be charged correctly if the Oyster card is validated at the pink validator when changing trains at Willesden Junction.

Underground and DLR

London Underground ticket barriers with yellow Oyster readers

Oyster card pay-as-you-go users must "touch in" at the start of a journey by London Underground or DLR, and "touch out" again at the end. The Oyster card readers automatically calculate the correct fare based on the start and end points of the journey and deduct that fare from the Oyster card. Pay-as-you-go funds are also used to cover any additional fares due from season ticket holders who have travelled outside the valid zones of their season ticket (see Travelcards above).

Passengers enter or exit most London Underground stations through ticket barriers which are operated by swiping an Oyster card or other valid ticket. Some tube stations (such as those at National Rail interchanges) and DLR stations have standalone validators with no barriers. In both instances, pay-as-you-go users are required to touch in and out.

London Overground

London Overground services are operated by TfL and Oyster pay-as-you-go users use their cards in the same way as on Underground journeys, touching their card on a card reader at the entry and exit points of their journey to calculate the fare due.

Buses

Oyster validators are placed at most entrances on London buses.

Users must touch the Oyster card only once at the point of boarding: as London buses have a single flat fare, there is no need to calculate an end point of the journey.

Some London bus routes cross outside the Greater London boundary before reaching their terminus. Pay-As-You-Go users are permitted to travel the full length of these route on buses operated as part of the London Bus network, even to destinations some distance outside Greater London.

'London Service Permit' Routes 402 and 477 have a reduced cash fare of £1 within Greater London which applies when an Oyster card with PAYG is shown. However, Oyster cards with Bus Passes and Travelcards loaded on them and Child Zip cards can be used free inside Greater London on Route 477 and to Knockholt Pound on Route 402.[26]

Hertfordshire bus route 84 from New Barnet to St. Albans via Potters Bar, as of 2 January 2012, no longer has any Oyster Card or contactless payment card validity on any part of the route, cash fares only. The buses are still red-liveried, but the destination displays are dot-matrix rather than TfL blinds, and there are no TfL roundels on the bus.

Trams

As London's trams operate on the same fare structure as buses, the rules are similar and users with pre-pay must touch the Oyster card only once at the point of boarding (users with Travelcards valid for the Tramlink zones need not touch in unless travelling to Wimbledon with a Travelcard not valid in zone 3).

An Oyster validator at a tram stop

A more complex arrangement exists at Wimbledon; tram passengers starting their journey at Wimbledon must pass through ticket gates in order to reach the tram platform, and therefore need to touch their Oyster card to open the barriers. They must then touch their Oyster card once again on the card reader on the Tramlink platform to confirm their journey as a tram passenger. Tram passengers arriving in Wimbledon must touch out to exit via the station gates, but must not touch out on the manual gate because this would be seen as a touch-in and cause a maximum cash fare of £7 to be charged to the card.[27]

River

A Thames Clipper river bus service

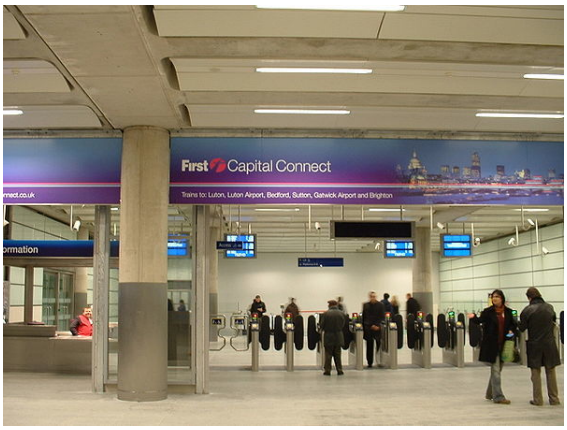
Passengers boarding a riverbus service must present their Oyster card to the on-board ticket inspector, who carries a hand-held card reader, and the appropriate fare is deducted from their pay-as-you-go balance.[28]

Oyster pay-as-you-go is valid only to purchase tickets for London River Services boats operated by Thames Clippers. Pay-as-you-go is not accepted for payment by other riverboat operators.

Emirates Air Line

Oyster cards are accepted on the Emirates Air Line cable route between Greenwich Peninsula and Royal Docks. The Emirates Air Line is outside of the London Travelcard validity. However, a 25% discount applies to Travelcard and Freedom pass holders for both single and return journeys.[29] The discount is automatically applied to Oyster card users, but only if their Travelcard is loaded onto their Oyster card. Freedom pass holders and visitors in possession of ordinary magnetic stripe Travelcards have to buy a cash ticket if they wish to take advantage of the discount.

National Rail



National Rail ticket barriers with yellow Oyster readers

Standalone Oyster readers provided at interchange stations between National Rail and the Tube

As with Underground and DLR journeys, Oyster PAYG users on National Rail must swipe their card at the start and end of the journey to pay the correct fare. PAYG funds may also be used to cover any additional fares due from season ticket holders who have travelled outside the valid zones of their season ticket (see Travelcards above).

Many large National Rail stations in London have Oystercard-compatible barriers. At other smaller stations, users must touch the card on a standalone validator.

Out of Station Interchange (OSI)

At a number of Tube, DLR, London Overground and National Rail stations which lie in close proximity, or where interchange requires passengers to pass through ticket barriers, an *Out of Station Interchange* (OSI) is permitted. In such cases, the card holder touches out at one station and then touches in again before starting the next leg of the journey. The PAYG fares are then combined and charged as a single journey. Examples include transferring between the Jubilee line at Canary Wharf and the DLR where Oyster card holders must swipe their card at the ticket barriers in the Tube station, and then touch in on the validator at the DLR station. Balham (National Rail) to/from Balham (Tube) is another OSI, as is Camden Town (Tube) to/from Camden Road (London Overground).[30] Failure to touch in or out on the validators in these circumstances will incur a maximum fare which is deducted from PAYG funds. In some cases (e.g. at West Hampstead NR stations) the OSI replicates interchanges which have existed for several decades before the invention of the Oyster system but were generally used with season tickets rather than day tickets.

Out of Station Interchanges can be temporary or permanent. A temporary arrangement may exist between two stations at short notice (routinely during weekend work but also when an emergency closure occurs). The two journeys that result are only charged as a single journey.

Recharging

When the PAYG balance runs low, the balance can be topped up at the normal sales points or ticket machines at London Underground or London Overground stations, Oyster Ticket Stops or some National Rail stations. All ticket offices at stations run by London Underground will sell or recharge Oyster cards, or handle Oyster card refunds. However, some Tube stations are actually operated by National Rail train operating companies, and their ticket offices will not deal with Oyster refunds. DLR ticket offices do not sell any Oyster card top-ups or handle refunds.

PAYG funds and Travelcard season tickets (but not Bus & Tram Passes) can also be purchased online via the Oyster online website or by calling the Oyster helpline; users must then select one station or tram stop where they will validate their card in order to load the funds or Travelcard purchased. This should be done as part of a normal journey to avoid the risk of paying an Oyster maximum fare.

If the customer is purchasing PAYG, the top up will be at the gates of their nominated station, or Tramlink stop the *next* day (ready for first train, provided they made the purchase before 11 PM the previous night). It will remain at the gates for 7 further days before dropping off the system.

If the customer purchases a Travelcard season ticket, it will 'arrive' at the gates, up to 5 days before the start date of the ticket and will remain there until 2 days after the ticket has started. If the customer does not make their pick up in time, it will take a further 14 days to refund automatically to the bank card they made the purchase with.[31] Top-ups of this type cannot be added from a reader on a bus.

For further information on recharging and renewals, see the section on Renewals in this article.

Auto top-up

Customers can set up and manage Auto top-up online for their existing Oyster card. They register a debit or credit card, make a PAYG top-up purchase (minimum £10) and select either £20 or £40 as the Auto top-up amount. Alternatively, a new Oyster card with Auto top-up and a minimum of £10 pay as you go can be ordered via Oyster online.

There is a constraint in the design, that requires a journey to be made via a nominated station, before auto top-up can be enabled. There are a number of services such as Thames Clippers, for which this initiation transaction is not offered.

Whenever the pay as you go balance falls below £10, £20 or £40 is added to the balance automatically when the Oyster card is touched on an entry validator. A light on the Oyster reader flashes to indicate the Auto top-up has taken place and an email is sent to confirm the transaction. Payment is then taken from the registered debit or credit card.

To ensure successful transactions, customers must record any changes to their billing address and update their debit or credit card details as necessary.

2.3.4 Oyster photocards

Oyster photocards, with an image of the authorised user on the card front, are issued to members of groups eligible for free or discounted travel. The cards are encoded to offer discounted fares and are currently available for students in full-time education (30% off season tickets), 16+ cards (half the adult-rate for single journeys on the Underground, London Overground, DLR and a limited number of National Rail services, discounted period Travelcards, free travel on buses and trams for students that live and attend full-time education in London) and for children under 16 years old (free travel on buses and trams and discounted single fares on the Underground, London Overground, DLR and most National Rail services). A 'Bus & Tram' Discount Card is specifically given to disadvantaged and 'unwaged' groups, primarily those on 'Job Seekers Allowance', 'Employment Support Allowance' and receivers of a variety of disabilities allowances, at half-fare rates for bus and tram services only; these cards simply charge the full rate on journeys not included in the discount scheme.

Student cards

Student Oyster photocards offering a 50% discount on period tickets, are available to full-time students over 18 at registered institutions within the area of the M25 motorway, an area slightly larger than Greater London, at a cost of £10.[32] Until the 2009–10 academic year, they cost £5 but required replacing each year of multiple-year courses. There is no discount for Pay-as-you-go, although many students hold the National Rail 16-25 Railcard, which can be added to an Oyster card at an Underground station ticket office to obtain a 1/3 reduction on off-peak caps and a 1/3 discount on off-peak Oyster single fares on all rail services. (NB peak National Rail fares may be cheaper with discounted paper tickets). A small selection of universities outside London have also registered on the scheme.

A replacement for lost/stolen cards cost £10 and involves applying for a replacement card online or by calling the Oyster helpline. A new photograph is not required. The funds/remaining travel is non-transferable to a new student Oyster photocard and is refundable instead. The refund of a lost/stolen Oyster card is based on the original pro-rata daily rate. Thus if you lose an annual student Oyster, the refund will not cover the remainder of the year due to the higher monthly/weekly pro-rata charges for the remainder of the year. This can leave students at a considerable disadvantage (adults can receive a replacement card with the remainder of their Travelcard loaded).

Since 8 September 2006, students at some London universities have been able to apply for their 18+ Oyster photocard online by uploading a digital photograph and paying with a credit or debit card.

Zip cards

On 7 January 2008, Transport for London unveiled the Zip card, a free Oyster photocard to be used by young people aged 18 years or under who qualify for free bus and tram travel within the capital, with effect from 1 June 2008. To qualify, one must live in a London borough (and still be in full-time education if between 16 and 18).[33] Children outside London (and indeed the UK) may also apply for a Visitor version of the Zip card (which offers free bus and tram travel for under 16s, and half-rate fares for 16–18-year-olds) online, which they must collect from one of TfL's Travel Information Centres. From 1 September 2010 a fee of £10 has been charged for the card.[24]

Freedom Passes and 60+ Oyster Cards

Freedom Passes are generally issued on what is in technical terms an Oyster card, though it does not bear that name. Freedom passes are free travel passes available to Greater London residents who are over a specified age (60 until March 2010, increasing in phases to 66 from March 2020) or with a disability specified in the Transport Act 2000; individual London boroughs have exceptional discretion to issue Freedom Passes to disabled people who do not meet the national statutory requirements (though they have to fund them). Travel is free at all times on the Tube, DLR, buses and Tramlink, and after 09:30 on most National Rail journeys entirely within the Greater London boundary. Holders cannot put any money or ticket products on a Freedom Pass; to travel outside these times, a separate Oyster card or other valid ticket is required.

Residents who are over 60 but who do not qualify for a Freedom Pass can obtain a similar *60+ Oyster Card* for a single fee. The outer boundary of the area in which Freedom Passes and 60+ Oyster Cards can be used is mostly the same as the area within which ordinary Oyster Cards can be used.[34][35][36] However there are notable exceptions: Oyster 60+ and Freedom passes are valid to both Dartford and Swanley stations, to which non-concessionary Oyster cards are invalid on train services but can be used on TfL bus services. This comes about because although both stations are outside of Greater London, both Dartford and Swanley have expanded sufficiently that parts now technically lie inside the Greater London boundary, though their postal addresses are still 'Dartford, Kent' and 'Swanley, Kent' respectively.[37] Residents of these areas are entitled to an Oyster 60+ or Freedom pass as appropriate and require access to a local station to use them. Also Oyster PAYG cards can be used to Broxbourne station but Freedom Passes and 60+ Oyster cannot be used north of Turkey Street or Enfield Lock stations.[38] This is solely because National Express East Anglia Railways has taken a decision to accept Oyster PAYG as far as Broxbourne. Both types of concessionary card have to be visually inspected at stations not equipped to read Oyster Cards; this also applies to any unequipped non-TfL buses whose routes accept the concessionary cards on journeys partly entering Greater London. This also applies to non TfL routes with readers that accept the national standard ITSO bus pass cards with which Oyster is not compatible.

Freedom Passes issued to qualifying persons are also an English National Concessionary Bus Pass. They look identical to concessionary bus passes but are additionally marked “Freedom Pass” in red. Unlike the Freedom pass, the 60+ Oyster card is not valid for concessionary travel outside of the area approved by the Greater London Authority.[39] This is because the concessionary bus travel scheme is centrally funded by government, but the Oyster 60+ and the Freedom Pass’s validity on Tube, tram and rail networks is funded locally by the Greater London Authority.

2.3.5 Oyster and credit card

The OnePulse card

Main article: OnePulse

A credit card variant of the Oyster card was launched by Barclaycard in September 2007 and is called OnePulse. The card combines standard Oyster card functionality with Visa credit card facilities. The Barclaycard OnePulse incorporates contactless payment technology, allowing most transactions up to £20 to be carried out without the need to enter a PIN (unlike the Chip and PIN system).[40]

In 2005, Transport for London shortlisted two financial services suppliers, Barclaycard and American Express, to add e-money payment capability to the Oyster card. Barclaycard was selected in December 2006 to supply the card,[41] but the project was then temporarily shelved.[42] The OnePulse card was later launched using a combination of Oyster and Visa, but with no e-money functionality.

In February 2014 Barclaycard announced that the OnePulse card would be withdrawn from use and all functionality would cease after 30 June 2014. Customers had their OnePulse card replaced with the Freedom Rewards credit card.[43]

2.4 Validity

A number of different ticket types can be held on an Oyster card, and validity varies across the different transport modes within London.

✔ = Valid.
✘ = Not valid.
✔ = **Heathrow Connect:** Not valid between Hayes and Harlington and Heathrow Airport.
✔ = **River**: PAYG only available on Thames Clipper; Travelcards only provide discount, not valid for travel.
✔ = **Cable car**: Travelcards only provide discount, not valid

for travel.
! = must include Zone 3,4,5 or 6

See also: Oyster card (pay as you go) on National Rail

2.4.1 TfL services

Oyster is operated by Transport for London and has been valid on all London Underground, London buses, DLR and London Tramlink services since its launch in 2003.

2.4.2 National Rail

The introduction of Oyster pay as you go on the National Rail commuter rail network in London was phased in gradually over a period of about six years (see Roll-out history). Since January 2010, PAYG has been valid on all London suburban rail services which currently accept Travelcards. Additionally, PAYG may be used at a selected number of stations which lie just outside the zones. New maps were issued in January 2010 which illustrates where PAYG is now valid.[44][45]

Certain limitations remain on National Rail, however; Oyster PAYG is not valid anywhere on Heathrow Express, Heathrow Connect between Hayes and Harlington and Heathrow Airport, on ANY Southeastern High speed services and was not available on the Olympic Javelin Shuttle.[46] Other airport express services (Gatwick Express, Stansted Express and First Capital Connect Luton Airport services) all run outside the Travelcard zones, so PAYG is not valid on those services either.

In November 2007, the metro routes operated by Silverlink were brought under the control of TfL and operated under the brand name London Overground. From the first day of operation, Oyster PAYG became valid on all Overground routes.[47]

2.4.3 London River Services

Since 23 November 2009, Oyster PAYG has been valid on London River Services boats operated by Thames Clippers only.[28] Oyster cards are accepted for all Thames Clippers scheduled services, the Hilton Docklands ferry, the “Tate to Tate” service and the O2 Express. Discounts on standard fares are offered to Oyster cardholders, except on the O2 Express. The daily price capping guarantee does not apply to journeys made on Thames Clippers.[48]

2.4.4 Emirates Air Line

Oyster card holders (PAYG, Travelcard or Freedom Pass) receive discounts on the Emirates Air Line cable car service across the River Thames between Greenwich and the Royal Docks, which opened in June 2012. Like London River Services, the cable car is a privately funded concern and is not fully integrated into TfL’s ticketing system.[49] To encourage use of the Air Line as a commuter service, substantial discounts are offered with a “frequent flyer” ticket which allows 10 journeys within 12 months.[50]

2.5 Pricing

The pricing system is fairly complex, and changes from time to time. The most up to date fares can be found on Transport for London’s FareFinder website.[51]

To encourage passengers to switch to Oyster, cash fares are generally much more expensive than PAYG fares (including Bus and Tram fares):

(Pricing correct as of August 2014) The single Oyster fare for a bus journey is £1.45, but capped at £4.40 for any number of trips in a day (including trips by Tram and tube). Cash is no longer accepted on London’s buses, but a contactless debit or credit card can be used in place of an Oyster card at the same fare. A single tram journey is charges as per a single bus journey, but the tram ticket machines do still accept cash (£2.40) for a single journey.[51]

Using pay as you go, a single trip on the Tube within Zone 1 costs £2.20 (compared to £4.70 cash), or £1.60 at peak times (£1.50 off peak or £4.70 for cash at any time) within any other single zone.[51] Journeys in multiple zones are progressively more expensive.[51]

The Oyster pay as you go system coupled with the zoned fare system inevitably gives rise to some quirks in the fares charged. A 9 stop journey between Clapham Junction and West Hampstead on the overground is charged at £1.60 at peak times (£1.50 off peak) whereas a 1 stop journey between Shoreditch High Street and Whitechapel on the same line costs £2.20 at all times.[51] This occurs because Shoreditch High Street is the only station on the line exclusively in zone 1, all others being in zone 2.[52] The cash fare is £4.70 in all cases and at all times.[51]

2.5.1 Fare capping

A 'capping' system was introduced on 27 February 2005, which means that an Oyster card will be charged no more than the nearest equivalent Day Travelcard for a day’s travel. The daily cap is currently [September 2014] £7 during off-peak hours and £8.40 during peak hours within zones 1-2, providing that the card has been touched in and out correctly for all rail journeys.[51] A lower cap of £4.40 applies if the day’s journeys are restricted to buses and trams only.[51]

Price capping does not apply to PAYG fares on London River Services boats.[48]

2.5.2 Railcard Discount

Holders of Disabled Persons, HM Forces, Senior, 16–25 National Rail Railcards and Annual Gold Cards (as of 23 May 2010) receive a 34% reduction in the off-peak PAYG fares and price cap; Railcard discounts can be loaded on at London Underground ticket offices only.

Disabled Person Railcard holders can also purchase an Off-Peak Day Travelcard for one accompanying adult for £3.00.[53]

2.5.3 Bus & Tram Discount

On 20 August 2007, a 'Bus and Tram Discount photocard' was launched for London Oyster card users who received Income Support. It allows cardholders to pay £0.70 for a single bus journey (currently capped at £2.40 per day), and to buy half price period bus passes. This was the result of a deal between Transport for London and Petróleos de Venezuela to provide fuel for London Buses at a 20% discount. In return Transport for London agreed to open an office in the Venezuelan capital Caracas to offer expertise on town planning, tourism, public protection and environmental issues.[54]

The deal with Venezuela was ended by Mayor Boris Johnson shortly after he took office, and the Bus and Tram Discount photocard scheme closed to new applications on 20 August 2008; Johnson said that "TfL will honour the discount [on existing cards] until the six-month time periods on cards have run out".[55]

The Bus and Tram Discount Scheme reopened on 2 January 2009, this time funded by London fare payers. The scheme has been extended to people receiving Employment Support Allowance (ESA) and to those receiving Job Seekers Allowance for 13 weeks or more.

2.5.4 River boat discounts

Boats operated by Thames Clippers offer a 10% discount on standard fares to Oyster PAYG users, except on their O2 Express service, and a 1/3 discount to passengers carrying Oyster cards which have been loaded with a valid period Travelcard.[48]

2.5.5 Penalty fares and maximum Oyster fare

In order to prevent "misuse" by a stated 2% of passengers, from 19 November 2006 pay as you go users who do not both 'touch in' at the start and 'touch out' at the end of their *rail network* journeys are charged a "maximum Oyster fare" – currently up to £7.20 (presumably depending on whether journeys have been made during or outside peak times) for most journeys, or more if the journey begins or ends at certain National Rail stations. Depending on the journey made, the difference between this maximum fare and the actual fare due is automatically refunded to the user's Oyster card upon touching out.

Users must touch in and out even if the ticket barriers are open. At stations where Oyster is accepted but that do not have ticket barriers, an Oyster validator will be provided for the purposes of touching in and out. The maximum Oyster fare applies even if the daily price cap has been reached and does not count towards the cap.

Maximum Oyster fares may be contested by telephone to the Oyster helpline on 0343 222 1234.[56] This involves providing the Oyster card number and the relevant journey details; further journeys appearing on the card are helpful to validate the user's claim.

If the claim is accepted then the maximum Oyster fare minus the cost of the journey will be refunded. The user will be asked to nominate and make a journey from a specific Tube, DLR, London Overground or National Rail station, or Tram stop. On touching in or out, the refund is loaded to the card. The customer should make the pick up as part of an actual journey. This is because when they touch the reader with their Oyster card, not only will the refund go on to the card, but a new journey will start.

The start date to pick up the refund can be the next day (at the earliest) and the refund will remain at the nominated station for 8 days in total. The customer does have the option to delay the start date for up to 8 days, and the refund will still remain at the gate for up to 8 further days. After this time the refund will be deleted from the gate line, and the customer will have to re-request the refund.

Customers claiming a refund must do so within 28 days of the overcharge.

Oyster users who do not touch in before making a journey may be liable to pay a penalty fare (currently £80) and/or reported for prosecution if caught by a revenue protection inspector.

2.6 Roll-out history

The roll-out of Oyster features and migration from the paper-based system has been phased. Milestones so far have been:

- London Underground ticket barriers, bus ticket machines, Docklands Light Railway stations and Tramlink stops fitted with validators. Cards issued to Transport for London, London Underground, and bus operator staff (2002)
- Cards issued to the public for annual and monthly tickets (2003)
- Freedom Passes issued on Oyster (2004)

- Pay as you go (PAYG, first called 'prepay') launched on London Underground, DLR, and the parts of National Rail where Underground fares had previously been valid. (January 2004)
- Off-Peak Oyster single fares launched (January 2004)
- Annual tickets available only on Oyster (2004)
- Monthly tickets available only on Oyster, unless purchased from a station operated by a train company rather than TfL (2004)
- Payg on buses (May 2004)
- Daily price capping (February 2005)
- Student Oyster Photocards for students over 18 (early 2005)
- Oyster Child Photocards for under 16s—free travel on buses and reduced fares on trains (August 2005)
- Automatic top-up (September 2005)
- Weekly tickets available only on Oyster (September 2005)[57]
- Oyster single fares cost up to 33% less than paper tickets (January 2006)[58]
- Auto top-up on buses and trams (June 2006)
- Journey history for Pay as you go transactions available online (July 2006)
- Ability for active and retired railway staff who have a staff travel card to obtain privilege travel fares on the Underground with Oyster (July 2006)
- £4 or £5 'maximum cash fare' charged for Pay as you go journeys without a 'touch in' and 'touch out' (November 2006)
- *Oyster card for visitors* branded cards launched and sold by Gatwick Express.[59]
- Oyster PAYG extended to London Overground (11 November 2007)
- Holders of Railcards (but not Network Railcard) can link their Railcard to Oyster to have PAYG capped at 34% below the normal rate since 2 January 2008.[60]
- Oyster PAYG can be used to buy tickets on river services operated by Thames Clipper (23 November 2009)[48]
- Oyster PAYG extended to National Rail (2 January 2010)[46]
- Contactless cards can be used on London Buses (End of 2012)
- Cash no longer accepted on buses. Cash ticket machines removed from bus stops in central London (Summer 2014)[61]

2.6.1 Roll-out on National Rail

See also: Oyster card (pay as you go) on National Rail

The National Rail network is mostly outside the control

Until January 2010, many rail operators did not accept Oyster PAYG and posted warning notices inside their stations.

of Transport for London, and passenger services are run by number of independent rail companies. Because of this, acceptance of Oyster PAYG on National Rail services was subject to the policy of each individual company and the roll-out of PAYG was much slower than on TfL services.[62] For the first six years of Oyster, rollout on National Rail was gradual and uneven, with validity limited to specific lines and stations.

Several rail companies have historically accepted London Underground single fares because they duplicate London Underground routes, and they adopted the Oyster PAYG on those sections of the line which run alongside the Underground. When TfL took over the former Silverlink Metro railway lines, PAYG was rolled out on the first day of operation of London Overground. As a consequence, some rail operators whose services run parallel to London Overground lines were forced to accept PAYG,[63] although only after some initial hesitation.[64][65]

Examples of these services include London Midland trains from Watford Junction to London Euston and Southern trains to Clapham Junction.

The process of persuading the various rail firms involved

2006

2008

The growing PAYG rail network 2006–08: more stations added

a long process of negotiation between the London Mayors and train operating companies. In 2005 Ken Livingstone (then Mayor of London) began a process of trying to persuade National Rail train operating companies to allow Oyster PAYG on all of their services within London, but a dispute about ticketing prevented this plan from going ahead.[66] After further negotiations, Transport for London offered to fund the train operating companies with £20m to provide Oyster facilities in London stations; this resulted in an outline agreement to introduce PAYG acceptance across the entire London rail network.[67]

TfL announced a National Rail rollout date of May 2009,[68] but negotiation with the private rail firms continued to fail and the rollout was delayed to 2010. Oyster readers were installed at many National Rail stations across London, but they remained covered up and not in use.[69] In November 2009 it was finally confirmed that PAYG would be valid on National Rail from January 2010.[46] The rollout was accompanied by the introduction of a new system of *Oyster Extension Permits* to allow travelcard holders to travel outside their designated zones on National Rail. This system was introduced to address the revenue protection concerns of the rail companies, but it was criticised for its complexity,[70][71] and was abolished on 22 May 2011.[24]

2.7 Impact

Since the introduction of the Oyster card, the number of customers paying cash fares on buses has dropped dramatically. In addition, usage of station ticket offices has dropped, to the extent that in June 2007, TfL announced that a number of their ticket offices would close, with some others reducing their opening hours. TfL suggested that the staff would be 're-deployed' elsewhere on the network, including as train drivers.

In August 2010 the issue of the impact of the Oyster card on staffing returned. In response to The National Union of Rail, Maritime and Transport Workers (RMT) ballot for a strike over planned job cuts, TfL stated that the increase in people using Oyster electronic ticketing cards meant only one in 20 journeys now involved interaction with a ticket office. As a result it aims to reduce staff in ticket offices and elsewhere while deploying more workers to help passengers in stations.[72]

2.8 Usage statistics

By June 2010 over 34 million cards have been issued of which around 7 million are in regular use. More than 80% of all tube journeys and more than 90% of all bus journeys use Oyster. Around 38% of all Tube journeys and 21% of all bus journeys are made using Oyster pay as you go. Use of single tickets has declined and stands at roughly 1.5% of all bus journeys and 3% of all Tube journeys.

2.9 Future

2.9.1 Beyond London

Oyster PAYG is now valid at c2c stations Purfleet, Ockendon, Chafford Hundred and Grays in Thurrock (Essex). However the paper Day Travelcard is currently cheaper than the maximum daily cap on Oyster PAYG due to the zone/fare information being directly copied from Watford Junction station.

Abellio Greater Anglia, the new operator of the Greater Anglia Rail Franchise, is committed to introducing Oyster PAYG as far as Shenfield (the terminus of the future Crossrail service) and Hertford East.[73] On 2 January 2013, Oyster PAYG was extended to Shenfield and Broxbourne.[74]

With regard to London's airports, TfL and BAA studied acceptance of Oyster Pay As You Go on BAA's Heathrow Express service and the Southern-operated Gatwick Express service in 2006, but ultimately BAA decided not to go ahead.[75] However, from 2014, Oyster facilities will be made available at Gatwick Airport station.[76]

2.9.2 Contactless payment cards

Transport for London started accepting contactless debit and credit cards on London Buses on 13 December 2012, with the aim of expanding the new system to other transport modes by 2013.[77] Transport for London further expanded the use of contactless cards to Underground; Tram and the Docklands railway from September 2014.[78] It is reported that TfL's long-term aim is to stop handling money and collecting fares altogether.[79] The same requirement to touch in and out on underground services applies to contactless cards. The same price capping that applies to the use of Oyster cards applies to the use of contactless cards (provided the same card is used for the day's journeys). Unlike Oyster cards, users of contactless cards cannot directly access their journey history. This is because the readers cannot write to the on card chip. Instead the use of the card is logged in TfL's central database, though the data is not downloaded from the readers until the following night. If it is desired to view the journey history, it is necessary to register the contactless card. Unlike an oyster card, a contactless card does not store credit (beyond the holder's credit limit) and there is no need or facility to add credit to the card.

An oyster card can have a longer term 'season' ticket loaded onto it (either at a ticket office or on line). Such a ticket can start on any day and be valid for a minimum of seven days and a maximum of one year. Unlike an oyster card, a contactless card can automatically apply a seven day travel card rate. If the card is regularly used between any Monday to Sunday period, an automatic cap is applied. The seven day period is fixed at Monday to Sunday, it cannot be *any* seven day period, unlike a seven day ticket applied to an oyster card and there is currently no automatic cap for longer periods.[80]

Since the oyster readers cannot write to a contactless card, the reader when touching out is unable to display the fare charged for the journey, as the card does not have the starting point stored in it. This is calculated overnight once the touch in and touch out information is downloaded from the gates and collated.[80] As with oyster, a failure to touch either in or out, charges the maximum possible fare. Transport for London state that if ticket inspection is taking place, that it is necessary to present the contactless card to the ticket inspector's portable oyster card reader. As the reader at the starting station cannot write to the contactless card and the card's use is not downloaded until the following night, it is not clear how the isolated portable card reader can determine if the card was used to touch into the system.

2.10 Visual design

2.10.1 Designs

Trial versions, Transport for London staff versions and the first version of the standard Oyster card for the public were originally released with the roundels on the front of the cards in red. Standard issues of the Oyster card have been updated since the first public release in order to meet TfL's Design Standards.

So far, there have been three issues of the standard Oyster card, including the original red roundel issue, but all three Oyster cards have retained their original dimensions of 85mm x 55mm, with Oyster card number and reference number located in the top right-hand corner and bottom right hand corner of the back of the card respectively, along with the terms and conditions.

The second issue of the standard Oyster card saw 'Transport for London' branding on the back of the card, along with the Mayor of London (having replaced just the 'LONDON' branding in the blue segment of the card's back). The roundel on the front of the card was changed from the colour red to white, as white was seen to represent Transport for London (whereas a red roundel is more known to represent London Buses).

The most recent issue of the standard Oyster card has TfL branding on its front, removed from the back of the card in the previous issue. The Mayor of London branding has also been moved from the blue segment on the back of the card to underneath the terms and conditions, where it is more prominent.

2.10.2 Oyster card holder/wallet

With the release of the Oyster card, TfL released an accompanying Oyster card holder to replace the existing designs, previously sponsored by companies such as Yellow Pages, Direct Line and IKEA, as well as London Underground's and London Buses own releases of the holder which came without advertising.

The official Oyster branded holders have only been redesigned twice, keeping up with various versions of the Oyster card. However, in 2007 the Oyster card wallets were redesigned and are now black.

In March 2007 the Oyster card holder was redesigned by British designers including Katharine Hamnett, Frostfrench and Gharani Strok for Oxfam's *I'm In* campaign to end world poverty. The designer wallets were available for a limited period of time from Oxfam's street teams in London who handed them out to people who signed up to the *I'm In* movement. Also, to celebrate 100 years of the Piccadilly line, a series of limited edition Oyster card wallets were commissioned from selected artists from the *Thin Cities* Platform for Art project. Any new Oyster cards are now given with black wallets that display the Oyster logo and the Transport for London roundel. The previous wallets handed out were sponsored by Ikea who

also sponsor the tube map, and did not display the Oyster or the London Underground logos.

In addition to the official wallets distributed by TfL, which may or may not carry advertising for a sponsor, Oyster card holders and wallets are sometimes used as a marketing tool by other organisations seeking to promote their identity or activities. Such items are normally given away free, either with products or handed out to the public.

2.10.3 Staff cards

The standard public Oyster card is blue but colour variants are used by transport staff.

2.10.4 Limited edition cards

A number of limited edition Oyster card variant designs exist. These are produced in limited quantities but otherwise function as standard Oyster cards. These include:

- 2011 Wedding of Prince William and Catherine Middleton
- 2012 Queen's Diamond Jubilee
- 2012 London Olympic Games
- 2013 150th Anniversary of London Underground
- 2014 Year of the Bus

Three design variations of the Oyster visitor cards also exist:

- Gold British Museum variant
- Standard blue skyscraper version
- Limited edition 2012 visitor card

2.11 Issues and criticisms

2.11.1 Touching out penalties

Card users sometimes forget to touch in or touch out, are unable to find the yellow readers or it may be too crowded to touch out. Such card users have either received penalty fares by revenue inspectors, been charged a maximum cash fare, or been prosecuted in courts which can issue high penalties.[81]

2.11.2 Extension fares

Holders of Travelcards can add pay as you go credit on their Oyster cards. This credit is used as 'extension fare' when the Oyster user travels beyond the zones in which their Travelcard is valid. This extension fare equals the regular Oyster fare for a journey from/to the respective station outside of the validity area of the Travelcard to/from the closest zone still covered by the Travelcard. To distinguish between Peak and Off-Peak fares, however, the start of the journey is taken into account. That means a traveller might be charged the (more expensive) peak fare as extension fare even if they had not yet left the area of validity of their Travelcard by the end of peak time.[82] Conversely, however, a journey starting in the covered zones shortly before the start of the peak time will be charged as off-peak.

2.11.3 Privacy

The system has been criticised as a threat to the privacy of its users. Each Oyster card is uniquely numbered, and registration is required for monthly or longer tickets, which are no longer available on paper. Limited usage data is stored on the card. Journey and transaction history is held centrally by Transport for London for up to eight weeks, after which the transactions and journey history are disassociated from the Oyster card and cannot be re-associated; full registration details are held centrally and not on individual Oyster cards; recent usage can be checked by anyone in possession of the card at some ticket machines.[83]

The police have used Oyster card data as an investigative tool, and this use is increasing. On 13 April 2006, TfL stated that “Between August 2004 and March 2006 TfL’s Information Access and Compliance Team received 436 requests from the police for Oyster card information. Of these, 409 requests were granted and the data were released to the police.”[84] However in response to another request in February 2012, “TfL said this had happened 5,295 times in 2008, 5,359 in 2009, 5,046 in 2010, and a record 6,258 in 2011”.[85]

Additionally, in 2008 news reports indicated that the security services were seeking access to all Oyster card data for the purposes of counter-terrorism. Such access is currently not provided to the security services.[86]

As yet, there have been no reports of customer data being misused, outside the terms of the registration agreement. There have been no reports of Oyster data being lost.

2.11.4 Design

The system has been criticised for usability issues in general system, website and top-up machine design.[87]

Oyster pay-as-you-go users, on London Underground,

DLR and National Rail (including London Overground) services are required always to "touch in" and "touch out" to cause the correct fare to be charged. This requirement is less obviously enforced at stations where there are only standalone yellow reader rather than ticket barriers. Without a physical barrier, pay-as-you-go users may simply forget to "touch in" or fail to touch their card correctly, which will result in a maximum fare being charged. Equally, if the barriers do not function (reading 'SEEK ASSISTANCE') and the TfL or train operating company staff member has to open the gates manually, then the maximum fare may be charged. If this occurs a refund may be requested by telephoning the Oyster helpline the day after the incident occurs (to allow time for the central computers to be updated); the overcharged amount can be added back to the pay-as-you-go balance on the card from the following day when the Oyster card is used to make a journey.

The use of Oyster cards on buses has been subject to criticism following a number of successful criminal prosecutions by TfL of bus passengers whose Oyster card, when checked by Revenue Protection Inspectors, did not show that the passenger had "touched in" correctly on boarding.[88][89][90] In particular, problems have been highlighted in connection with the quality of error messages given to passengers when touching in has failed for any reason. In one case, a passenger successfully appealed against his conviction for fare evasion when the court noted that the passenger believed he had paid for his journey because the Oyster reader did not give sufficient error warning.[91][92]

In 2011, London Assembly member Caroline Pidgeon obtained figures from the Mayor of London which revealed that in 2010, £60million had been taken by TfL in maximum Oyster fares. The statistics also detailed a "top ten" of stations where maximum fares were being collected, notably Waterloo and London Bridge. In her criticism of the figures, Pidgeon claimed that "structural problems" with the Oyster system were to blame, such as faulty equipment failing to register cards and difficulty in obtaining refunds.[93][94] A report by BBC London highlighted the system of "autocomplete" (in which Oyster cards journeys are automatically completed without the need to physically touch out, exceptionally used when large crowds are exiting stations) as particularly problematic.[95]

2.11.5 Technical faults

In January 2004, on the day that the pay-as-you-go system went live on all Oyster cards, some season ticket passengers were prevented from making a second journey on their travelcard. Upon investigation each had a negative prepay balance. This was widely reported as a major bug in the system.[96] However, the reason for the "bug" was that some season ticket holders were passing through zones not included on their tickets. The existing paper system could not prevent this kind of misuse as the barriers only checked if a paper ticket was valid in the zone the barrier was in.

On 10 March 2005 an incorrect data table meant that the Oyster system was inoperable during the morning rush hour. Ticket barriers had to be left open and pay as you go fares could not be collected.[97]

On 12 July 2008 an incorrect data table disabled an estimated 72,000 Oyster cards, including Travelcards, staff passes, Freedom Passes, child Oyster cards and other electronic tickets. The Oyster system was shut down and later restarted during traffic hours. Some customers already in the system were overcharged. Refunds were given to those affected and all disabled cards were replaced. Freedom Pass holders had to apply to their local authority for replacement passes (as these are not managed by TfL).[98]

A further system failure occurred two weeks later on 25 July 2008, when pay as you go cards were not read properly.[99]

2.11.6 The difference between pay-as-you-go and Travelcards

Transport for London promoted the Oyster card at launch with many adverts seeking to portray it as an alternative to the paper Travelcard. In late 2005 the Advertising Standards Authority ordered the withdrawal of one such poster which claimed that Oyster pay as you go was "more convenient" than Travelcards with "no need to plan in advance". The ASA ruled that the two products were not directly comparable, mainly because the pay as you go facility was not valid on most National Rail routes at the time.[100][101]

Transport for London has made a significant surplus from excess fares deducted for those travelling using PAYG and failing to touch out as they exit stations. According to information obtained under the Freedom of Information Act[102] TfL made £32m from pay as you go cards of which £18m was maximum fares for failing to touch out. Only £803,000 was paid in refunds, showing that whilst customers can apply for a refund, most do not. The maximum fares for failing to touch out were introduced late 2006.[103]

2.11.7 Validity on National Rail

Until the availability of Oyster pay-as-you-go on the whole of the National Rail suburban network in January 2010, the validity of PAYG was not consistent across different modes of transport within London, and this gave rise to confusion for Oyster pay-as-you-go users.[104] Many passengers were caught out trying to use Pay as you go on rail routes where it was not valid.[105][106]

On some National Rail routes where pay-as-you-go was valid, Oyster validators had not been installed at some intermediate stations. While Oyster pay-as-you-go users could legally travel along those lines to certain destinations, they were not permitted to board or alight at intermediate stations. If their journey began or ended at an intermediate station, they would be unable to touch out and consequently be liable for penalty fares or prosecution.[107][108]

The complexity of Oyster validity on these routes was criticised for increasing the risk of passengers inadvertently failing to pay the correct fare. Criticism was also levelled at train operating companies for failing to provide adequate warnings to passengers about Oyster validity on their routes and for not installing Oyster readers at certain stations.[109][110]

TfL published guides to the limitations of pay-as-you-go validity[111] diagrammatic maps illustrating PAYG validity were published in November 2006 by National Rail,[112] but these were rarely on display at stations and had to be obtained from transport websites.[109]

2.11.8 Online and telesales

Oyster card ticket renewals and pay-as-you-go top-ups made online allow users to make purchases without the need to go to a ticket office or vending machine. However there are certain limitations to this system:

- tickets and pay-as-you-go funds can only be added to the Oyster card from the day after purchase (if bought online);
- users must select a station or tram stop where they must touch in or out as part of a normal journey to complete the purchase (as cards cannot be credited remotely);
- users must nominate the station in advance – failure to enter or exit via this station means that the ticket is not added to the card;
- tickets purchased in this way cannot be added from a bus reader (due to these not being fixed in a permanent location).[31]

2.11.9 Security issues

In June 2008, researchers at the Radboud University in Nijmegen, the Netherlands, who had previously succeeded in hacking the OV-chipkaart (the Dutch public transport chip card), hacked an Oyster card, which is also based on the MIFARE Classic chip. They scanned a card reader to obtain its cryptographic key, then used a wireless antenna attached to a laptop computer to brush up against passengers on the London Underground and extract the information from their cards. With that information they were able to clone a card, add credit to it, and use it to travel on the Underground for at least a day.[113][114] The MIFARE chip manufacturers NXP Semiconductor sought a court injunction to prevent the publication of the details of this security breach, but this was overturned on appeal.[115]

The Mifare Classic—which is also used as a security pass for controlling entry into buildings—has been criticised as having very poor security, and NXP criticised for trying to ensure security by secrecy rather than strong encryption. “The security of Mifare Classic is terrible. This is not an exaggeration; it’s kindergarten cryptography. Anyone with any security experience would be embarrassed to put his name to the design. NXP attempted to deal with this embarrassment by keeping the design secret”.[116] Breaching security on Oyster cards should not allow unauthorised use for more than a day, as TfL promises to turn off any cloned cards within 24 hours, but a cloned Mifare Classic can allow entry into buildings that use this system for security.

2.12 Strategic research

Transport for London, in partnership with academic institutions such as MIT, has begun to use the data captured by the Oyster smartcard system for strategic research purposes, with the general goal of using Oyster data to gain cheap and accurate insights into the behaviour and experience of passengers. Specific projects include estimation of Origin-Destination Matrices for the London Underground,[117][118] analysis of bus-to-bus and bus-to-tube interchange behaviour,[119] modelling and analysis of TfL-wide fare policy changes,[120] and measurement of service quality on the London Overground.[121]

2.13 See also

- Contactless smartcards on the railways of Britain
- List of smart cards
- Octopus Card
- Oyster card (pay as you go) on National Rail
- Presto card
- Radio-frequency identification

2.14 References

[1] http://tfl.gov.uk/cdn/static/cms/images/london-rail-and-tube-services-map-250.gif [Rail Map]

[2] "What is Oyster?". Transport for London. n.d. Retrieved 22 December 2013.

[3] "Join in the celebrations across the capital this summer with a limited edition Summer Oyster card" (Press release). Transport for London. 13 June 2012. Retrieved 11 September 2012.

[4] "Projects and Planning Panel, Project Monitoring papers". Transport for London. 9 January 2014. p. 12. Retrieved 3 January 2014.

[5] "Oyster card: The highs and lows of Oyster". *Computer Weekly*. 14 July 2008. Retrieved 10 August 2008.

[6] Gannon, Mark J. (April 2006). "Funding London Underground's investment programme". Chartered Institute of Logistics and Transport. Archived from the original on 25 July 2011.

[7] Vermeulen, Amanda (9 August 2008). "Oyster card contractor fired after £1m failures". *Financial Times* (London). Retrieved 10 August 2008.

[8] "TfL terminates Oyster contract". *ZDNet*. 8 August 2008. Retrieved 10 August 2008.

[9] "TfL salvages Oyster brand in deal with EDS, Cubic". *ZDNet*. 19 November 2008. Retrieved 24 November 2008.

[10] Goodman, Matthew (10 August 2008). "Oyster name en route to history". *The Times* (London). Retrieved 10 August 2008. (subscription required)

[11] "Oyster brand bought for £1m by Transport for London". *BBC News*. 12 April 2010. Retrieved 13 April 2010.

[12] MIFARE.net. "Easing travel in London's congested public transport network".

[13] Balaban, Dan (21 January 2010). "Transport for London to Discard Mifare Classic". *NFC Times* (Paris).

[14] "Foiling the Oyster card". *SpyBlog*. 16 February 2004. Archived from the original on 3 February 2006.

[15] Stephens, Alex (6 August 2008). "Make an Oyster watch and risk a fine, says TfL". *thelondonpaper*.

[16] Judge, Peter (22 May 2008). "Linux opens London's Oyster". *Zdnet*. Retrieved 13 March 2011.

[17] "Conditions of Carriage". Transport for London. 8 September 2013. Retrieved 22 December 2013.

[18] Transport for London – Oyster online shop

[19] "Oyster refunds & replacements". Transport for London. 27 March 2014.

[20] "Changes to Oyster card deposit from 17 May" (Press release). Transport for London. 22 April 2009.

[21] "Mayor confirms 2011 fares at level signalled last year and protects all free and concessionary travel" (Press release). Transport for London. 20 October 2010.

[22] "National Rail Enquiries – Oyster issued". ATOC. Retrieved 13 March 2011.

[23] "Fares 2013: Bus and tram". Transport for London. Retrieved 22 December 2013.

[24] "Where you can use Oyster". Transport for London. Retrieved 22 May 2011.

[25] Transport for London. "Online Oyster FAQ question". Retrieved 24 April 2010.

[26] "Guide to using tickets and PAYG on buses outside London". Transport for London. 31 October 2009.

[27] "Touching in and out". Transport for London. 2012. Retrieved 11 September 2012.

[28] "Mayor announces Oysterisation of Thames Clippers river services" (Press release). Transport for London. 23 November 2009. Retrieved 22 December 2013.

[29] http://www.emiratesairline.co.uk/faq Emirates Air Line FAQ

[30] "Out of Station Interchange (OSI)". Oyster and National Rail (independent guide). 26 May 2010. Retrieved 31 May 2010.

[31] Transport for London. "Oyster online help". Retrieved 17 November 2007.

[32] "Application fee to be introduced for new Zip Oyster photocard applications from 1 September" (Press release). Transport for London. 23 July 2010.

[33] "Zip on board with Oyster" (Press release). Transport for London. 7 January 2008.

[34] 'London Connections' map published jointly by TfL and National Rail.

[35] 60+ London validity map published by TfL.

[36] Freedom pass validity map published by TfL.

[37] The British postal address system has many such anomolies.

[38] http://www.tfl.gov.uk/cdn/static/cms/documents/pay-as-you-go-tarrifs-national-rail.pdf Oyster area map

[39] 60+ oyster card validity

[40] "Barclaycard OnePulse". Barclaycard. Retrieved 4 January 2010.

[41] "New deal brings Oyster and Barclaycard Visa onto one card" (Press release). Transport for London. 13 December 2006.

[42] "TfL shelves Oyster e-money". *The Register*. 9 May 2006.

[43] http://www.tfl.gov.uk/tickets/29678.aspx

[44] "London Tube Map". London Insider. November 2009. Retrieved 26 November 2009.

[45] Barney, Katharine (23 November 2009). "Travel revolution: Oyster rail will cut fares by 30%". *London Evening Standard*.

[46] "One ticket for London as Oysterisation of rail and river confirmed" (Press release). Transport for London. 23 November 2009.

[47] "Silverlink lines under new management as Mayor launches London Overground" (Press release). Transport for London. 12 November 2007.

[48] "Oyster pay as you go". Thames Clipper. 23 November 2009. Retrieved 26 November 2009.

[49] "FAQ". *Emirates Air Line website*. Retrieved 19 June 2012.

[50] "Fares on the Emirates Air Line". Transport for London. June 2012. Retrieved 11 September 2012.

[51] "TfL Single Fare Finder". Transport for London. August 2014. Retrieved 1 August 2014.

[52] London Tube map Published May 2014

[53] "What discounts do I get?". Disabledpersons-railcard.co.uk. Retrieved 13 March 2011.

[54] "Mayor's 'cheap oil deal' slammed". BBC News. 13 September 2006. Retrieved 25 January 2008.

[55] "Johnsons Clash Over Half-Priced Fares". Mayorwatch.co.uk. 19 August 2008. Retrieved 13 March 2011.

[56] http://www.tfl.gov.uk/corporate/media/newscentre/metro/27609.aspx

[57] – *A faster, easier 7 Day Travelcard on Oyster*

[58] Transport for London – *Big savings in 2006 by switching from cash for single journeys to Oyster*

[59] Mayor of London – *Plane, Train and Oyster*. 6 March 2007.

[60] TfL – *Discounted daily price capping – Railcards*. 8 February 2008.

[61] http://www.standard.co.uk/news.transport/london-buses-will-stop-accepting-cash-fares-from-summer-2014 News announcement

[62] National Rail – Oyster Pay as you go (PAYG) on National Rail

[63] Transport for London (19 November 2007). "TfL welcomes Oyster on London Midland services". *Press Release*. Archived from the original on 24 November 2007. Retrieved 19 November 2007.

[64] "All change at Watford Junction". *The Watford Observer*. 12 November 2007. Retrieved 17 November 2007.

[65] "London Midland admits error". *The Watford Observer*. 15 November 2007. Retrieved 19 November 2007.

[66] Lydall, Ross (12 January 2005). "New row over Oyster card". *Evening Standard*. Retrieved 10 August 2008.

[67] "Train operators' Oyster acceptance welcomed". TfL. 31 January 2007. Archived from the original on 18 May 2008. Retrieved 10 August 2008.

[68] Waugh, Paul (12 May 2008). "Boris plans to 'Oysterise' overground rail services by next May". *Evening Standard*. Retrieved 10 August 2008.

[69] "Watchdog fury at Oyster delay". 12 May 2009.

[70] "You Are Leaving Zone 2: Please Have Your Exit Visa Ready". The Londonist. 16 November 2009. Retrieved 19 November 2009.

[71] "Oyster PAYG On National Rail From 2 Jan". London Reconnections. 13 November 2009. Retrieved 4 January 2010.

[72] "London Tube Workers Vote to Strike". *Press Article*. 11 August 2010. Retrieved 20 August 2010.

[73] Greater Anglia rail franchise Department for Transport

[74] Transport for London. "National Rail | Transport for London". Retrieved 2012-12-13.

[75] "Oyster Pay As You Go on Heathrow Connect – a Freedom of Information request to Transport for London – WhatDoTheyKnow:". Whatdotheyknow.com. 11 January 2012. Retrieved 12 January 2012.

[76] TfL Projects and Planning Panel, 'The Future of London's Ticketing Technology' para 4.3b, Feb 2014 http://www.tfl.gov.uk/cdn/static/cms/documents/ppp-20140226-item04-future-ticketing.pdf

[77] "Contactless payment". Transport for London. 2012. Retrieved 11 September 2012.

[78] TfL website on contactless cards

[79] Balaban, Dan (24 February 2011). "Transport for London to Accept Bank Cards on Entire Network in 2012". *NFC times*. Retrieved 7 March 2011.

[80] Transport for London leaflet "Contactless travel"

[81] Anger at Oyster cards 'rip-off" as millions hit for not 'touching out'. Retrieved 10 November 2012

[82] Personal correspondence with TfL

[83] Scullion, Aaron (25 September 2003). "Smart cards track commuters". BBC News. Retrieved 4 February 2011.

[84] OysterCardRFI – Letter from TfL in response to a freedom of information request

[85] – Letter from TfL in response to a freedom of information request, February 2012

[86] Gaby Hinsliff, political editor (16 March 2008). "MI5 seeks powers to trawl records in new terror hunt". *The Guardian* (UK). Retrieved 13 March 2011.

[87] Matt Stephens (13 February 2005). "The Oyster Gotcha". Retrieved 17 November 2007.

[88] Mendick, Robert (6 June 2008). "Archbishop's PA branded a fare dodger for 20p bus fare slip-up". *Evening Standard* (London). Retrieved 19 November 2009.

[89] Moore-Bridger, Benedict (17 April 2008). "Student gets criminal record for sake of 90p". *Evening Standard* (London). Retrieved 19 November 2009.

[90] "Court threat over £1.20 bus fare". BBC News. 20 October 2005.

[91] "Fine for 90p Oyster error quashed". BBC News. 15 August 2008. Retrieved 19 November 2009.

[92] video report

[93] Pidgeon, Caroline (25 February 2011). "News from Caroline Pidgeon – Oyster overcharging at a station near you". *London Assembly Press Release*. Retrieved 7 March 2011.

[94] Jones, Alan (7 January 2011). "Rail passengers 'ripped off' by Oyster card system". *The Independent* (London). Retrieved 7 March 2011.

[95] Edwards, Tom (reporter) (25 February 2011). *Overcharge possibility 'a drawback' of Oyster card* (iPlayer/FLV). BBC London. Retrieved 7 March 2011.

[96] BBC News – *Inquiry into Tube's Oyster card*

[97] BBC News – *'£50,000 lost' in Oyster failure*

[98] "All go free in Oyster cards fiasco". *Evening Standard*. 12 July 2008.

[99] "Thousands go free on Tube as Oyster breaks down again". *Evening Standard*. 25 July 2008. Retrieved 25 July 2008.

[100] BBC News – *Travel card poster ordered down*

[101] Advertising Standards Authority – ASA Adjudication: *Objections to four posters for the Oyster card, a ticket for travel within London.*

[102] "TfL taps into £18m from Oyster fines", thelondonpaper, page 6, Friday 30 May 2008

[103] Rail bosses bank £32m Oyster windfall from errors by passengers

[104] House of Commons Transport Committee (2008). *Ticketing and Concessionary Travel on Public Transport*. The Stationery Office. p. 16. ISBN 978-0-215-51449-3. Retrieved 4 January 2009.

[105] "Our Year" (PDF). *Annual Review 2006*. London TravelWatch. 2006. p. 11. Archived from the original on 14 October 2007. Retrieved 6 March 2008. "But the non-availability of Oyster's pay-as-you-go 'electronic purse' facility on most National Rail routes has caused widespread confusion to passengers, many of whom have been charged penalty fares as a result. We have pressed the train companies to publicise their rules more effectively, and to be more sympathetic in their treatment of honest travellers who break them unknowingly."

[106] Roger Evans (3 August 2008). "Oyster cards at Romford Station". Retrieved 4 January 2010.

[107] "Where can I use my Oyster card on National Rail?". National Rail. 2008. Archived from the original on 10 January 2008. Retrieved 10 August 2008. (archived page)

[108] Jonathan Moyes (8 February 2008). "Anger over Oyster card station 'snub'". Waltham Forest Guardian. Retrieved 6 March 2008. "Wood Street in Walthamstow, Highams Park and Chingford on the Chingford to Liverpool Street line(...) do not currently have Oyster card readers(...) despite Oyster machines being installed in stations from Liverpool Street to Walthamstow Central on the same line."

[109] London Assembly member Roger Evans criticises arrangements at Romford: "Oyster card absence branded a disgrace". Romford Recorder. 1 August 2008. Retrieved 12 August 2008.

[110] "Campaign pushes to install Oyster card readers". 19 August 2008: Total Essex. Retrieved 4 January 2010.

[111] "Using Oyster to pay-as-you-go on National Rail services". Transport for London. Archived from the original on 10 August 2007. Retrieved 19 August 2007.

[112] "Map of Oyster Pay as you go on National Rail" (PDF). National Rail. Archived from the original on 28 November 2006. Retrieved 30 December 2006. Also available from TfL website "Map of Oyster Pay as you go on National Rail" (PDF). Transport for London. Retrieved 19 August 2007.

[113] Brenno de Winter (18 June 2008). "Radboud onderzoekers kraken ook Oyster card". Webwereld. Retrieved 18 June 2008. "Radboud onderzoekers kraken ook Oyster card." (Dutch)

[114] Alexander Lew (24 June 2008). "Hackers Crack London Tube's Ticketing System". *Wired*. Retrieved 3 July 2008. "Dutch security researchers rode the London Underground free for a day after easily using an ordinary laptop to clone the smartcards commuters use to pay fares"

[115] "Oyster card hack to be unveiled". BBC News. 21 July 2008. Retrieved 21 July 2008.

[116] Schneier, Bruce (7 August 2008). "Why being open about security makes us all safer in the long run". *The Guardian* (London).

[117] Gordillo, Fabio (2006). "The value of automated fare collection data for transit planning: an example of rail transit OD matrix estimation".

[118] Chan, Joanne (2007). "Rail transit OD matrix estimation and journey time reliability metrics using automated fare data".

[119] Seaborn, Catherine (2008). "Application of Smart Card Fare Payment Data to Bus Network Planning in London, UK".

[120] Zureiqat, Hazem (2008). "Fare Policy Analysis for Public Transport: A Discrete-Continuous Modeling Approach Using Panel Data".

[121] Frumin, Michael (2010). "Automatic Data for Applied Railway Management: Passenger Demand, Service Quality Measurement, and Tactical Planning on the London Overground Network".

2.15 External links

- Official website
- Transport for London
- Transport for London Design Standards
- Transport for London FareFinder

Chapter 3

OV-chipkaart

The **OV-chipkaart** is a contactless smart card system used for all public transport in the Netherlands. The Dutch abbreviation "OV" stands for "openbaar vervoer" (public transport). First introduced in the Rotterdam metro in April 2005, it has subsequently been rolled out to other areas and travel modes. It fully replaced the national strippenkaart system for buses, trams and metros in 2011 and the paper ticket system for rail travel in July 2014.

The OV-chipkaart is available in disposable form (for occasional passengers, such as tourists) and reusable versions (for frequent travellers, either in anonymous or personalized forms).

3.1 History and coverage

The OV-chipkaart is a collaborative initiative of five large public transport operators in the Netherlands: the main rail operator NS, the bus operator Connexxion and the municipal transport operators of the three largest cities: GVB (Amsterdam), HTM (The Hague) and RET (Rotterdam), though all public transport operators in the Netherlands now use the system. It is operated through a joint venture named Trans Link Systems (*TLS*).

The OV-chipkaart system was first implemented in the Rotterdam Metro in April 2005. The Amsterdam Metro followed suit in 2006 by accepting the card as an alternative method of payment. All trams and buses in Rotterdam accepted the OV-chipkaart from June 2007 onwards, and coverage in Amsterdam was extended to all trams and buses in November 2008. Traditional paper tickets and the OV-chipkaart were used concurrently in the Amsterdam and Rotterdam metropolitan areas until mid 2010, when the OV-chipkaart became the only valid fare system. Paper-based, single-use tickets and the national strippenkaart system were subsequently phased out throughout the country on an area-by-area basis. The strippenkaart system was formally abandoned in November 2011.[2]

Within the national rail system, the principal rail operator Nederlandse Spoorwegen (NS) started implementing the OV-chipkaart for rail journeys in October 2009. Regional operators followed suit. Traditional paper tickets were finally abandoned in July 2014 for both NS and regional rail operators.[3] Single or return tickets, used by incidental travellers and tourists, are still available at ticket machines and service counters, but are now loaded on a disposable OV-chipkaart which means that the ticket must be validated by "checking in" at a ticket barrier or card reader before boarding the train.

Since July 2014, the OV-chipkaart has become the only ticketing system in all public transport in the Netherlands, although the system has not been adopted on most of the Frisian Islands and in the Caribbean Netherlands.

3.2 Travelling with the OV-chipkaart

The OV-chipkaart works in two ways: either as a stored-value card which is used to travel on pre-loaded credit (Dutch: *reizen op saldo*); or as a means of storing so-called "travel products" (Dutch: *reisproducten*) such as single or return rail tickets, day passes, seasonal tickets and discount plans.

3.2.1 Checking in and out

One "checks in" at the beginning of one's journey and "checks out" at the end of the journey by holding the card in front of an OV-chipkaart card reader. Card readers are placed at the station entrance (metro and train) or on board of the vehicle (bus, tram, light rail).[4] A successful check-in is usually signaled with a green light and a short beep, while check-out also gives a green light and usually two short beeps.

When changing between vehicles (e.g. from bus to bus, bus to tram, bus to train), the user must check out when leaving the first vehicle and check in when entering the second vehicle. When transferring between *trains* or *metros* from the *same* operator (e.g. from NS train to NS train), checking out and in is not necessary.[5]

When travelling on credit, a deposit is deducted from the card's credit balance upon checking in. The amount of

OV-chipkaart reader in a bus.

Ticket barriers at Amsterdam Centraal railway station.

the deposit is generally €4 for bus, tram and metro journeys. For train journeys, the deposit is €20, although with some discount plans loaded on the card, the deposit is only €10. Upon checking out, the deposit is automatically refunded to the card with the price of the journey deducted. The journey price consists of a basic fare and a fare-per-kilometer. The basic fare is only calculated once per journey, which means that only the per-kilometer fare is calculated after transferring to another vehicle (provided that no more than 35 minutes have passed checking out and in). Journey fares vary regionally and are determined periodically by regional transport boards.

The deposit is not refunded if the user fails to check out at the end of the journey. As this normally means that the user pays more than the quoted fare for a journey, the deposit system aims to deter misuse of the system. In the event of a machine failure (e.g. if all card validators are out of service), the excess fee paid can be claimed back from the transport operator.

3.2.2 Use on trains and metros

Larger metro stations in Amsterdam and Rotterdam as well as the larger railway stations in the Netherlands are only accessible by passing through a ticket barrier. These barriers are designed to make access to the platforms (and therefore any vehicle) impossible without checking in beforehand. When checking in at a ticket barrier, the gates are opened after a deposit has been collected from the stored value on the passenger's OV-chipkaart or when an appropriate travel product has been acknowledged. If no travel product (such as a single or return journey) has been loaded or no deposit can be collected because of insufficient funds on the card, the ticket barriers will refuse to open and access to the station is denied. Since traditional paper tickets will continue to be used for some rail journeys, such as for international travel or in case of e-tickets, at least one ticket barrier will be equipped with both an OV-chipkaart reader and a barcode reader. The latter can be used to open the gate by scanning the square barcode on paper tickets.[6]

Smaller railway and metro stations are often not equipped with ticket barriers. Instead, free-standing validator units (card readers) are used for checking in and out. While ticket barriers are either programmed for checking in or for checking out, depending on whether the turnstile is used for entering or leaving a station, free-standing units can be used for both checking in and out.

During a rail or metro journey, conductors or ticket inspectors use mobile card readers to verify whether passengers have properly checked in with their OV-chipkaart before boarding.

3.2.3 Use on buses, trams and light rail

All buses, trams and RandstadRail (light rail) vehicles have card readers on board, located near the doors within the vehicle itself (except on trams in Utrecht, where card readers are placed at the tram stops). On most buses and trams in the Netherlands, passengers are required to board at a door near the driver or conductor, which allows for the check-in process to be monitored. As checking out and leaving the vehicle is more difficult to monitor, passengers travelling on credit can evade part of their fare by checking out before the vehicle has arrived at the stop or station where they intend to alight. It is for this reason that ticket inspections continue to take place randomly.

Forgetting to check out when disembarking a vehicle will

cause a passenger to lose their check-in deposit. The screens on card validators and ticket barriers will display the amount deducted from the stored credit and remaining balance when a passenger checks out.

3.3 Technology

As all public transport operators use their own card readers for checking in and out, passenger transferring from one operator to another must first check out with the first operator and then check in with the second operator.

The first OV-chipkaarts were based on Mifare technology, developed by NXP Semiconductors. The anonymous and personal versions of the card used Mifare Classic 4K chips, protected from unlawful access by security keys known only to the vendor. The disposable, single-use cards used the cheaper Mifare Ultralight chips that do not employ any encryption, and can be read by anyone.

The Mifare Crypto-1 encryption algorithm was believed to have been cracked in 2007.[7] Further hacking reports in 2010 and 2011 and several technological reviews made it clear that the original chip technology was not sufficiently secure. Since 2011, card operator TLS has been issuing cards based on the more fraud-resistant Infineon SLE 66 microcontroller.[8] From 2012, TLS has upgraded to the Infineon SLE 77 technology.[9]

3.4 Types of cards

The OV-chipkaart is available in three versions: the disposable OV-chipkaart, the anonymous OV-chipkaart, and the personal OV-chipkaart. Disposable cards are for one-time or short-period use, the latter two types valid for five years and can be used as a stored-value card, also known as electronic purse or e-purse.

Ticket machine at railway station offering the possibility to obtain a disposable OV-chipkaart, comparable to the traditional paper singles and returns.

3.4.1 Disposable OV-chipkaart

The disposable version of the OV-chipkaart (Dutch: *eenmalige chipkaart* or *wegwerpkaart*) is made of thick paper, suitable for short use. It can only be used for simple travel products (such as single or return journeys on trains or unlimited travel on a city or regional network for a certain period of time). Since it cannot be topped up with credit, it is not usuable as a stored-value card. Disposable tickets are intended for passengers who use public transport infrequently. Journey fares are normally higher when travelling on a disposable chipcard rather than on a reusable (anonymous or personal) OV-chipkaart.

Disposable train or metro tickets must be purchased before boarding at a ticket machine or service counter and validated by checking in at a ticket barrier or validator unit (card reader). For train journeys, the traditional paper singles and returns have been replaced by disposable OV-chipkaart tickets as of July 2014.[10] Because of a surcharge of €1 for rail journeys on a disposable chipcard, frequent travellers are encouraged to travel on pre-loaded credit with a reusable anonymous or personal OV-chipkaart. Since July 2014, international rail tickets are also issued in the form of disposable chipcards when purchased at at Dutch railway station, but without a surcharge. Traditional paper tickets for international travel purchased online or abroad will remain valid.

For bus and tram journeys, disposable tickets are available at ticket machines or on board and must also be validated by checking in and out.

3.4.2 Anonymous OV-chipkaart

The anonymous OV-chipkaart (Dutch: *anonieme OV-chipkaart*) is a reusable, credit-card-sized card for passengers who travel more frequently. It is sold at public transport ticket machines and service counters for a one-time fee, normally €7.50. Unlike the disposable version,

it can be used as a stored-value card: users travel on pre-loaded credit and pay per kilometer. The credit balance (*saldo*) of the card is "topped up" at vending machines at stations or shops. It can be used on all modes of transport and with all transport operators immediately after loading credit. For travel on pre-loaded credit on NS trains, however, cards purchased at vending machines of other transport operators much first be activated once at an NS ticket machine by adding credit to the balance.[11]

Yellow vending machines, found at supermarkets or tobacco shops, to be used to top up OV-chipkaart credit.

An anonymous OV-chipkaart must have a minimum credit balance of €4 for travel on buses, trams and metros and €20 for trains in order to be able to "check in" at a ticket barrier or card reader at the beginning of the journey. The appropriate journey price is calculated when checking out at the end of each journey. The card is transferable between persons, although only one person can use an anonymous OV-chipkaart at any one time.

Anonymous cards can also be used to store a limited number of non-personalized travel products, such as one-hour or day passes for specific public transport systems. For example, the Amsterdam public transport operator GVB offers day passes valid for up to seven days which can be loaded on an anonymous card or purchased on a disposable card, but season tickets can only be loaded on a personal OV-chipkaart.[12]

3.4.3 Personal OV-chipkaart

The personal OV-chipkaart (Dutch: *persoonlijke OV-chipkaart*) is similar to the anonymous version of the OV-chipkaart in the sense that it can be used as a stored-value card to travel on pre-loaded credit. In addition, it can be used to load seasonal passes, discount plans and other travel products of a period longer than a single month or travel products which are only available to specific groups, such as older persons or students. A personal card is non-transferable and is issued with a photograph and date of birth of the user. The card can be cancelled with the credit being blocked in case it is lost or stolen, and it can be set to automatically top up (Dutch: *automatisch opladen*) when the electronic purse credit drops below a certain level.

Personal OV-chipkaarts are issued by card operator TLS for a one-time fee, normally €7.50. It can be applied for online at the OV-chipkaart website or by paper application form provided by a public transport operator. Some transport operators provide personal cards for free when purchasing seasonal passes or discount plans, with the pass or plan already loaded on the card. The personal OV-chipkaart is intended for use by residents of the Netherlands, as a Dutch permanent address and bank account must be provided when applying for a card. Residents of Belgium, Germany and Luxembourg can apply for a personal OV-chipkaart by using a Dutch bank account or PayPal. If payment is processed with PayPal, however, it will not possible to use the automatic top-up feature.[13]

3.5 Issues and criticisms

The implementation of the OV-chipkaart system in all public transport systems in the Netherlands has proven to be a complex and time-consuming project. The process, which started in 2005 and was finally completed in 2014, has been plaged with cost-overruns, delays because of technical difficulties, planning and co-ordination problems, and resistance from consumer groups and politicians because of concerns over the safety and user-friendliness of the system, resulting in waning public support.[14] Nevertheless, as passengers are becoming accustomed to the smard card system, recent surveys published by card operator TLS indicate that user satisfaction is increasing.[15]

3.5.1 Passengers not checking out

Passengers travelling on pre-loaded credit must always check out at the end of their journey in order for the deposit, which was deducted upon check-in, to be reimbursed to their OV-chipkaart. While checking out is unavoidable at railway or metro stations closed off with

ticket barriers, stations with free-standing validator units as well as trams and buses can be exited without checking out. An estimated 2% of occasional passengers and 0.5% of frequent travellers forget to check out.[16] Even though passengers can reclaim their deposit, many are not aware of their failure to check out. In addition, the reimbursement procedure requires submitting a paper or online form with the transport operator concerned[17] which some passenger consider too cumbersome in relation to the amount lost. An investigation commissioned by passenger associations showed that the check-out problem results in an estimated profit of nearly €23 mln a year for public transport operators. About half of this amount would go to NS as the principle rail operator. Transport operators have questioned the validity of the numbers, claiming the total amount is not more than a few million euros and that they are willing to reimburse lost deposits. However, an NS spokesperson responded, "the travelers who have forgotten to check out have to announce themselves".[18]

The check-out problem was one of the reasons for the Rotterdam public transport operator RET to begin an experiment in March 2014 with travelling on account, whereby OV-chipkaart users do not need to pre-load credit or maintain a minimum balance for the deposit to be deducted, but receive a bill for their journeys at the end of the month.[19]

3.5.2 Privacy concerns

Privacy has been a major subject of debate from the start of the OV-chipkaart implementation process. The OV-chipkaart system allows for collecting travel data and connecting those to personal data of passengers, thereby creating an opportunity for public transport operators and card operator TLS to track passengers or build an image of an individual's travel behaviour. Travel data are collected and stored by both TLS and the public transport operator concerned. Under the OV-chipkaart privacy policy, data are stored for a maximum of 18 months in accordance with the Dutch Data Protection Act.[20]

After an investigation by the Dutch Data Protection Authority in 2007 of the effect of the system in the Amsterdam metro, it concluded that the Amsterdam public transport operator GVB violated Dutch privacy legislation by storing personal and travel data together. In response, GVB and other operators decided to store these sets of data separately. By doing so, the Data Protection Authority concluded, "the risk of the unlawful monitoring of individual people's travel behaviour will be limited considerably."[21]

In a lawsuit brought by a group of students against main rail operator NS in 2012, the district court in Utrecht ruled that NS did not act unlawfully by required students to check in and check out when travelling on their government-sponsored public transport pass, which could only by used when loaded on a personal OV-chipkaart. The rail operator, the court concluded, had a legitimate reason for mandating the check-in process, because it was a reasonable way of ensuring that passengers have a valid title for their journey.[22]

In 2012, the Dutch Data Protection Authority found that rail operator NS violated privacy legislation by using personal data for marketing purposes. Passengers wanting to use their anonymous OV-chipkaart to travel on NS trains were required to activate their card via the NS website. During the activation process, an e-mail address had to be provided which was subsequently used for marketing purposes. The Data Protection Authority stated that passengers travelling on an anonymous card may reasonably expect their anonymity to be respected. In response, NS decided to adjust the activation process in accordance with the ruling. Entering an e-mail address is now no longer required when activating an anonymous card for NS travel.[23]

3.5.3 Security

Independent technological reviews and several hacking attempts continue to draw attention to the security and safety of the OV-chipkaart system. In 2007, students at the University of Amsterdam discovered several vulnerabilities in the disposable, single-use chipcard technology used by municipal transport operator GVB, which allowed for the cards to be reprogrammed for unlimited use. Card operator TLS was able to fix the software bug which allowed for such interference.[24] German hackers reported later that year that the security code of the MIFARE Classic chips used for anonymous and personal OV-chipkaarts could easily be hacked with technology available for less than 100 euros.[25] A security analysis by the Netherlands Organisation for Applied Scientific Research (TNO), commissioned early 2008 by TLS in response to the hacking claims, concluded that the MIFARE Classic chipcard should indeed be replaced because of serious security shortcomings, but that urgent migration to a more secure and better encrypted chip technology was not necessary because of the low value of OV-chipkaarts for criminal exploitation. A counter expertise review by the Information Security Group at Royal Holloway, University of London, commissioned by the Dutch Ministry of Transport, Public Works and Water Management, concluded that the TNO report underestimated (later acknowledged by TNO itself) the risk of more systematic hacking attempts in the future and the ease with which these could be carried out, as well as the loss of confidence in the system this may cause with passengers. The review recommended a replacement of all existing chip cards in circulation to be completed at the time the OV-chipkaart system was to be implemented nationally in 2009 and, in the long term, that phased migration of different card types to newer chip technology was important to keep the system future-proof.[26]

When the Royal Holloway review was presented to the Dutch House of Representatives in April 2008, coordinating state secretary Huizinga expressed doubt as to whether the planning for the national roll-out of the OV-chipkaart and subsequent phasing out of the traditional paper ticketing systems, which was set to be completed by January 1, 2009, was still realistic. The government majority in the House nevertheless voted to continue with the roll-out process after a parliamentary committee visit to London where lawmakers had discussions with Transport for London officials and representatives of consumer organisation London TravelWatch about the technical features of the Oyster Card, which operates on the same chip technology.[27] Nevertheless, it took until October 2011 until the phase-out of the traditional paper tickets for buses, metros, and trams was completed in all regios. Despite new publications that year of successful hacking attempts as well as fraud schemes,[28] transport minister Schultz concluded that the card was safe enough to fully replace the thirty-year old strippenkaart system.[29]

Later in 2011, it appeared that TLS had started issuing a new version of the OV-chipkaart, which no longer uses the Dutch MIFARE chip but a chip manufactured by the German semiconductor company Infineon.[30] In 2013, TLS reported that because of this new chip, fraud had been reduced to a mimimum.[31]

3.6 Awards

In April 2007, the OV-chipkaart received a Computerworld Honors Program Laureate award.[32]

3.7 See also

- List of smart cards
- Oyster card - a similar scheme in London, United Kingdom

3.8 References

[1] The OV-Chipcard cannot be used on the Frisian Wadden islands (see Arriva.nl) and the BES-islands.

[2] "Strippenkaart disappears from all buses, trams and metros". DutchNews.nl. 2011-11-03.

[3] "Paper train tickets vanish". DutchNews.nl. 2014-07-09.

[4] "Checking in and out". OV-chipkaart. Retrieved 2014-07-13.

[5] "Transfers". OV-chipkaart. Retrieved 2014-07-13.

[6] "Opening the gates on an international journey". NS International. Retrieved 2014-07-16.

[7] "Mifare ? Little Security, Despite Obscurity". *24th Chaos Communication Congress*. Retrieved 2008-01-14.

[8] "Nieuwe OV-chip gaat fraude tegen (New OV-chipkaart to prevent fraud)" (in Dutch). WebWereld.nl. 2011-10-06.

[9] "Trans Link: veiliger OV-chip niet meer van NXP" (in Dutch). WebWereld.nl. 2012-02-09.

[10] "Paper train tickets set to vanish in July". DutchNews.nl. 2014-05-24.

[11] "Preparing your OV-chipkaart for use". Nederlandse Spoorwegen. Retrieved 2014-07-13.

[12] "What card is best for you?". GVB. Retrieved 2014-07-16.

[13] "Apply". OV-chipkaart. Retrieved 2014-07-13.

[14] "OV-Chipkaart roll-out creeps forward". Railway Gazette. 2009-01-16.

[15] "OV-chipkaart appreciated". OV-chipkaart.nl. 2013-03-28.

[16] "Students champion at forgetting to check out of trains". DutchNews.nl. 2011-06-05.

[17] "Forgot to check out". OV-chipkaart.nl. Retrieved 2014-07-17.

[18] "OV travellers lose €23m by not checking out". NL Times. 2014-06-19.

[19] "Rotterdam experiments with travel account". NL Times. 2014-03-03.

[20] "Privacy". OV-chipkaart.nl. Retrieved 2014-07-16.

[21] "Annual Report 2007 (summary in English)". Dutch Data Protection Authority. Retrieved 2014-07-16.

[22] "Geen privacybezwaren tegen verplicht inchecken OV-chipkaart ("No privacy objections against mandatory check-in with OV-chipkaart")" (in Dutch). Dirkzwager Intellectuele Eigendom & IT. 2012-04-11.

[23] "Na optreden CBP wijzigt NS gebruik reisgegevens OV-chipkaart ("After CBP ruling, NS changes travel data usage")" (in Dutch). Dutch Data Protection Authority (CBP). 2012-08-28.

[24] "Security Evaluation of the disposable OV-chipkaart". System and Network Engineering, University of Amsterdam. 2007-07-01.

[25] "Mifare: Little Security, Despite Obscurity". 24th Chaos Communication Congress. 2007-12-28. Retrieved 2014-07-17.

[26] "Counter Expertise Review of the TNO Security Analysis of the Dutch OV-Chipkaart". Royal Holloway, University of London, Information Security Group - Smart Card Centre. 2008.

[27] "Kamer wil doorgaan met OV-chipkaart (House wants to proceed with OV-chipkaart)" (in Dutch). Nu.nl. 2008-05-07.

[28] “Public transport smart card fraud under investigation”. DutchNews.nl. 2011-07-06.

[29] “Public transport smart card is safe enough, says minister”. DutchNews.nl. 2011-02-26.

[30] “Nieuwe OV-chipkaart is bestand tegen fraude (New OV-chipkaart is fraud resistant)" (in Dutch). Nu.nl. 2011-10-06.

[31] “TLS: bijna geen fraude meer met ov-chipkaart (TLS: Almost No OV-Chipkaart Fraud Anymore)" (in Dutch). Tweakers.net. 2013-06-28.

[32] “The Computerworld Honors Program: Trans Link Systems smart card (OV-chipkaart)".

3.9 External links

- OV-chipkaart, official website
- Trans Link Systems, operator website

Chapter 4

MIFARE

MIFARE is the NXP Semiconductors-owned trademark of a series of chips widely used in contactless smart cards and proximity cards. According to the producers, billions of smart card chips and many millions of reader modules have been sold.[1] The technology is owned by NXP Semiconductors (spin off from Philips Electronics in 2006) with headquarters in Eindhoven, Netherlands, and main business sites in Nijmegen, Netherlands, and Hamburg, Germany.

The MIFARE name covers proprietary technologies based upon various levels of the ISO/IEC 14443 Type A 13.56 MHz contactless smart card standard.

4.1 Variants

The technology is embodied in both cards and readers (also referred to as a Proximity Coupling Device which is suitable to use).

The MIFARE name (derived from the term MIkron FARE Collection System) covers seven different kinds of contactless cards:

MIFARE Classic employ a proprietary protocol compliant to parts (but not all) of ISO/IEC 14443-3 Type A, with an NXP proprietary security protocol for authentication and ciphering.

MIFARE Ultralight low-cost ICs that employ a proprietary protocol compliant to ISO/IEC 14443-3 Type A.

MIFARE Ultralight C the first low-cost ICs for limited-use applications that offer the benefits of an open Triple DES cryptography

MIFARE DESFire are smart cards that comply to ISO/IEC 14443-4 Type A with a mask-ROM operating system from NXP.

MIFARE DESFire EV1 includes AES encryption.

MIFARE DESFire EV2 includes MIsmartApp, Transaction MAC, Unlimited Applications

MIFARE Plus drop-in replacement for MIFARE Classic with certified security level (AES 128 based)

MIFARE SAM AV2 secure access module that provides the secure storage of cryptographic keys and cryptographic functions

4.1.1 MIFARE Classic

The MIFARE Classic card is fundamentally just a memory storage device, where the memory is divided into segments and blocks with simple security mechanisms for access control. They are ASIC-based and have limited computational power. Thanks to their reliability and low cost, those cards are widely used for electronic wallet, access control, corporate ID cards, transportation or stadium ticketing.

The MIFARE Classic 1K offers 1024 bytes of data storage, split into 16 *sectors*; each sector is protected by two different keys, called *A* and *B*. Each key can be programmed to allow operations such as reading, writing, increasing value blocks, etc. MIFARE Classic 4K offers 4096 bytes split into forty sectors, of which 32 are same size as in the 1K with eight more that are quadruple size sectors. MIFARE Classic mini offers 320 bytes split into five sectors. For each of these card types, 16 bytes per sector are reserved for the keys and access conditions and can not normally be used for user data. Also, the very first 16 bytes contain the serial number of the card and certain other manufacturer data and are read only. That brings the net storage capacity of these cards down to 752 bytes for MIFARE Classic 1k, 3440 bytes for MIFARE Classic 4k, and 224 bytes for Mini. It uses an NXP proprietary security protocol (Crypto-1) for authentication and ciphering.

The Samsung TecTile NFC tag stickers use MIFARE Classic chips. This means only devices with an NXP NFC controller chip can read or write these tags. At the moment BlackBerry phones, the Nokia Lumia 610 (August 2012[2]), the Google Nexus 4 and Nexus 10 (October 2013[3]) can't read/write TecTile stickers.

MIFARE Classic encryption has been compromised; see below for details.

4.1.2 MIFARE Ultralight and MIFARE Ultralight EV1

The MIFARE Ultralight has only 512 bits of memory (i.e. 64 bytes), without cryptographic security. The memory is provided in 16 *pages* of 4 bytes. Cards based on these chips are so inexpensive it is often used for disposable tickets for events such as the Football World Cup 2006. It provides only basic security features such as one-time-programmable (OTP) bits and a write-lock feature to prevent re-writing of memory pages but does not include cryptography as applied in other MIFARE based cards.

MIFARE Ultralight EV1[4] introduced in November 2012 the next generation of paper ticketing smart card IC for limited-use applications that offers solution developers and operators the maximum flexibility for their ticketing schemes and additional security options. It comes with several enhancements above the original MIFARE Ultralight

- 384 and 1024 Bits user memory product variants
- OTP, Lock Bits, configurable counters for improved security
- Three independent 24-bit-one-way counters to stop reloading
- Protected data access through 32-bit password
- NXP Semiconductors originality signature function, this is an integrated originality checker and is an effective cloning protection that helps to prevent counterfeit of tickets.

Key applications:

- Limited-use tickets in public transport
- Event ticketing (stadiums, exhibitions, leisure parks)
- Loyalty

4.1.3 MIFARE Ultralight C

Introduced at the Cartes industry trade show in 2008, MIFARE Ultralight C is part of NXP's low-cost MIFARE offering (disposable ticket). With Triple DES, MIFARE Ultralight C uses a widely adopted standard, enabling easy integration in existing infrastructures. The integrated Triple DES authentication provides an effective countermeasure against cloning.

Key features:

- Fully compliant with ISO/IEC 14443 parts 1-3, Type A (including anti-collision)
- 1536 bits (192 bytes) EEPROM memory
- Protected data access via 3-pass Triple DES authentication
- Memory structure as in MIFARE Ultralight (pages of 4 byte)
- Backwards compatibility to MIFARE Ultralight due to compatible command set
- 16 bit one-way counter
- Unique 7 bytes serial number (UID)

Key applications for MIFARE Ultralight C are Public Transportation, Event Ticketing, Loyalty and NFC Forum Tag Type 2.

4.1.4 MIFARE DESFire

The MIFARE DESFire (MF3ICD40) was introduced in 2002 and is based on a core similar to SmartMX, with more hardware and software security features than MIFARE Classic. It comes pre-programmed with the general purpose MIFARE DESFire operating system which offers a simple directory structure and files. They are sold in four variants: one with Triple-DES only and 4 KB of storage, and three with AES (2, 4 or 8 KB; see MIFARE DESFire EV1). The AES variants have additional security features, e.g., CMAC. MIFARE DESFire uses a protocol compliant with ISO/IEC 14443-4.[5] The card is based on an 8051 processor with 3DES/AES crypto accelerator, making very fast transactions possible.

The maximal read/write distance between card and reader is 10 centimetres (3.9 in), but actual distance depends on the field power generated by the reader and its antenna size.

In 2010 NXP announced the discontinuation of the MIFARE DESFire (MF3ICD40) after it had introduced its successor MIFARE DESFire EV1 late 2008. In October 2011 researchers of Ruhr University Bochum[6] announced that they had broken the security of MIFARE DESFire (MF3ICD40), which was acknowledged by NXP.,[7] see DESFire Attacks

4.1.5 MIFARE DESFire EV1

(previously called DESFire8)

New evolution of MIFARE DESFire card, broadly backwards compatible. Available with 2 KB, 4 KB and 8 KB NV-Memory. Other features include:

- Support for random ID
- Support for 128-bit AES
- Hardware and Operating System is Common Criteria certified at level EAL 4+

MIFARE DESFire EV1 was publicly announced in November 2006.

Key applications:

- Advanced public transportation
- Access management

4.1.6 MIFARE DESFire EV2

New evolution of MIFARE DESFire card, broadly backwards compatible.[8] New features include:

- MIsmartApp enabling to offer or sell memory space for additional applications of 3rd parties without the need to share secret keys
- Transaction MAC to authenticate transactions by 3rd parties
- Virtual Card Architecture for privacy protection
- Proximity check against relay attacks

MIFARE DESFire EV2 was publicly announced in November 2013

4.1.7 MIFARE Plus

MIFARE Plus is a replacement card for the MIFARE Classic. It provides an easy upgrade of existing infrastructures toward high security. Data management is identical to the MIFARE Classic; however, the security management requires the modification of the installed reader base. Other features include:

- 2 Kbytes or 4 Kbytes of memory
- 7 or 4 bytes UID, with optional support for random UID
- Support for 128-bit AES
- Common Criteria certified at level EAL 4+
- MIFARE Plus S for simple migration or MIFARE Plus X with many eXpert commands
- Security upgrade with cards in the field.

Key applications:

- Public Transportation
- Access management, e.g. employee, school or campus cards
- Electronic toll collection
- Car parking
- Loyalty programs

It is less flexible than MIFARE DESFire EV1.

MIFARE Plus was publicly announced in March 2008 with first samples in Q1 2009.[9]

MIFARE Plus, when used in older transportation systems that do not yet support AES on the reader side, still leaves an open door to attacks. Though it helps to mitigate threats from attacks that broke the Crypto-1 cipher through the weak random number generator, it does not help against brute force attacks and cryptoanalytic attacks.[10] During the transition period from MIFARE Classic to MIFARE Plus where only a few readers might support AES in the first place, it offers an optional AES authentication in Security Level 1 (which is in fact MIFARE Classic operation). This does not prevent the attacks mentioned above but enables a secure mutual authentication between the reader and the card to prove that the card belongs to the system and is not fake.

4.1.8 MIFARE SAM AV2

MIFARE SAMs are not contactless smartcards. They are Secure access modules designed to provide the secure storage of cryptographic keys and cryptographic functions for terminals to access the MIFARE products securely and to enable secure communication between terminals and host (backend). MIFARE SAMs are available from NXP in the contact-only module (PCM 1.1) as defined in ISO/IEC 7816−2 and the HVQFN32 format.

Key features:

- Compatible with MIFARE portfolio solutions
- Supports MIFARE, 3DES and AES cryptography
- Key diversification
- Secure download and storage of keys
- 128 key entries
- ISO/IEC 7816 baud rate up to 1.5 Mbit/s
- X-mode functionality

Integrating a MIFARE SAM AV2 in a contactless smart card reader enables a design which integrates high-end cryptography features and the support of crypto authentication and data encryption/decryption. Like any SAM, it offers functionality to store keys securely, and perform authentication and encryption of data between the contactless card and the SAM and the SAM towards the backend. Next to a classical SAM architecture the MIFARE SAM AV2 supports the X-mode which allows a fast and convenient contactless terminal development by

connecting the SAM to the microcontroller and reader IC simultaneously.

MIFARE SAM AV2 offers AV1 mode and AV2 mode where in comparison to the SAM AV1 the AV2 version includes Public Key Infrastructure (PKI), Hash functions like SHA-1, SHA-224, and SHA-256. It supports MIFARE Plus and a secure host communication. Both modes provide the same communication interfaces, cryptographic algorithms (Triple-DES 112-bit and 168-bit key, MIFARE Crypto1, AES-128 and AES-192, RSA with up to 2048-bit keys), and X-mode functionalities.

4.2 Applications

MIFARE products can be used in different applications:[11]

- Automated fare collection system
- ID Cards
- Access Management (Corporate Access, Home Access, Hotel Access, Smart Lock, Logical Access, used for Identification or Section Control)
- Campus cards (Identification, Access, Copy machines, Vending Machines, Micropayment at Cafeterias, Transportation...)
- Loyalty cards (reward points)
- Tourist cards
- Micropayment(Mobile wallet, contactless payment, cashless payment)
- Road tolling
- Transport ticketing
- Event ticketing
- Mobile ticketing
- Citizen card
- Membership cards
- Parking
- Library cards
- Fuel cards
- Hotel key cards
- NFC Tag(NFC apps, MIFARE4Mobile)
- Taxi cards
- Smart meter
- Museum Access Cards
- Product Authentication
- Production control
- Health cards
- Ferry Cards
- Car rentals
- Fleet Management
- Amusement parks
- Bike rentals
- Blood donor cards
- Information services
- Interactive exhibits
- Interactive lotteries
- Password storage
- Smart advertising
- Social welfare
- Waste management

Former most access systems used MIFARE Classic but today these systems switch to MIFARE DESFire because this product has more security than MIFARE Classic.

4.3 History

- 1994 — MIFARE Classic 1k contactless technology introduced.
- 1996 — First transport scheme in Seoul using MIFARE Classic 1k.
- 1997 — MIFARE PRO with Triple DES coprocessor introduced.
- 1999 — MIFARE PROX with PKI coprocessor introduced.
- 2001 — MIFARE UltraLight introduced.
- 2002 — MIFARE DESFire introduced, microprocessor based product.
- 2004 — MIFARE DESFire SAM introduced, secure infrastructure counterpart of MIFARE DESFire.
- 2006 — MIFARE DESFire EV1 is announced as the first product to support 128-bit AES
- 2008 — MIFARE Plus is announced as a drop-in replacement for MIFARE Classic based on 128-bit AES

- 2008 — MIFARE Ultralight C is introduced as paperticket IC featuring Triple DES Authentication
- 2010 — MIFARE SAM AV2 is introduced as secure key storage for readers AES, Triple DES, PKI Authentication
- 2012 — MIFARE Ultralight EV1 introduced, backwards compatible to MIFARE Ultralight but with extra security.
- 2013 — MIFARE DESFire EV2 is announced with improved performance, security&privacy and multiapplication support

MIFARE was developed by Mikron; the name stands for *MI*kron *FARE*-collection System. It was acquired by Philips in 1998. Mikron sourced silicon from Atmel in the US, Philips in the Netherlands, and Siemens in Germany.

Infineon Technologies(then Siemens) licensed MIFARE from Mikron in 1994[12] and developed both stand alone and integrated designs with MIFARE compatible functions. Infineon currently produces various derivatives based on MIFARE technology including 1K memory (SLE66R35) and various microcontrollers (8 bit (SLE66 series), 16 bit (SLE7x series), and 32 bit (SLE97 series) with MIFARE emulations, including devices for use in USIM with Near Field Communication.[13]

Motorola tried to develop MIFARE-like chip for wired-logic version but finally gave up. The project expected one million cards per month for start, but that fell to 100,000 per month just before they gave up the project.[14]

In 1998 Philips licensed MIFARE to Hitachi[15] Hitachi licensed MIFARE for the development of the contactless smart card solution for NTT's IC telephone card which started in 1999 and finished in 2006. In the NTT contactless IC telephone card project, three parties joined: Tokin-Tamura-Siemens, Hitachi (Philips-contract for technical support), and Denso (Motorola-only production). NTT asked for two versions of chip, i.e. wired-logic chip (like MIFARE Classic) with small memory and big memory capacity. Hitachi developed only big memory version and cut part of the memory to fit for the small memory version.

The deal with Hitachi was upgraded in 2008 by NXP (by then no longer part of Philips) to include MIFARE Plus and MIFARE DESFire to the renamed semiconductor division of Hitachi Renesas Technology.[16]

In 2010 NXP licensed MIFARE to Gemalto. In 2011 NXP licensed Oberthur to use MIFARE on SIM cards. These licensees are developing Near Field Communication products[17][18]

4.4 Security of MIFARE Classic, MIFARE DESFire and MIFARE Ultralight

The encryption used by the MIFARE Classic card uses a 48 bit key.[19]

A presentation by Henryk Plötz and Karsten Nohl[20] at the Chaos Communication Congress in December 2007 described a partial reverse-engineering of the algorithm used in the MIFARE Classic chip. Abstract and slides[21] are available online. A paper that describes the process of reverse engineering this chip was published at the August 2008 USENIX security conference.[22]

In March 2008 the Digital Security[23] research group of the Radboud University Nijmegen made public that they performed a complete reverse-engineering and were able to clone and manipulate the contents of an OV-Chipkaart which is a MIFARE Classic card.[24] For demonstration they used the Proxmark device, a 125 kHz / 13.56 MHz research instrument.[25] The schematics and software are released under the free GNU General Public License by Jonathan Westhues in 2007. They demonstrate it is even possible to perform card-only attacks using just an ordinary stock-commercial NFC reader in combination with the libnfc library.

The Radboud University published three scientific papers concerning the security of the MIFARE Classic:

- A Practical Attack on the MIFARE Classic
- Dismantling MIFARE Classic
- Wirelessly Pickpocketing a MIFARE Classic Card

In response to these attacks, the Dutch Minister of the Interior and Kingdom Relations stated that they would investigate whether the introduction of the Dutch Rijkspas could be brought forward from Q4 of 2008.[26]

NXP tried to stop the publication of the second article by requesting a preliminary injunction. However, the injunction was denied, with the court noting that, "It should be considered that the publication of scientific studies carries a lot of weight in a democratic society, as does informing society about serious issues in the chip, because it allows for mitigating of the risks."[27][28]

Both independent research results are confirmed by the manufacturer NXP.[29] These attacks on the cards didn't stop the further introduction of the card as the only accepted card for all Dutch public transport the OV-chipkaart continued as nothing happened[30] but in October 2011 the company TLS, responsible for the OV-Chipkaart announced that the new version of the card will be better protected against fraud.[31]

The MIFARE Classic encryption Crypto-1 can be broken in about 200 seconds on a laptop,[32] if approx. 50

bits of known (or chosen) key stream are available. This attack reveals the key from sniffed transactions under certain (common) circumstances and/or allows an attacker to learn the key by challenging the reader device.

The attack proposed in[33] recovers the secret key in about 40 ms on a laptop. This attack requires just one (partial) authentication attempt with a legitimate reader.

Additionally there are a number of attacks that work directly on a card and without the help of a valid reader device.[34] These attacks have been acknowledged by NXP.[35] In April 2009 new and better card-only attack on MIFARE Classic has been found. It was first announced at the Rump session of Eurocrypt 2009.[36] This attack was presented at SECRYPT 2009.[37] The full description of this latest and fastest attack to date can also be found in the IACR preprint archive.[38] The new attack improves by a factor of more than 10 all previous card-only attacks on MIFARE Classic, has instant running time, and it does not require a costly precomputation. The new attack allows to recover the secret key of any sector of MIFARE Classic card via wireless interaction, within about 300 queries to the card. It can then be combined with the nested authentication attack in the Nijmegen Oakland paper to recover subsequent keys almost instantly. Both attacks combined and with the right hardware equipment such as Proxmark3, one should be able to clone any MIFARE Classic card in not more than 10 seconds. This is much faster than previously thought.

DESFire Attacks

In October 2011 David Oswald and Christof Paar of Ruhr-University in Bochum, Germany, detailed how they were able to conduct a successful “side-channel” attack against the card using equipment that can built for nearly $3,000. called “Breaking Mifare DESFire MF3ICD40: Power Analysis and Templates in the Real World,”[39] They stated that System integrators should be aware of the new security risks that arise from the presented attacks and can no longer rely on the mathematical security of the used 3DES cipher. Hence, in order to avoid, e.g. manipulation or cloning of smartcards used in payment or access control solutions, proper actions have to be taken: on the one hand, multi-level countermeasures in the backend allow to minimize the threat even if the underlying RFID platform is insecure,” In a statement[40] NXP said that the attack would be difficult to replicate and that they had already planned to discontinue the card at the end of 2011. NXP also stated “Also, the impact of a successful attack depends on the end-to-end system security design of each individual infrastructure and whether diversified keys – recommended by NXP – are being used. If this is the case, a stolen or lost card can be disabled simply by the operator detecting the fraud and blacklisting the card, however this operation assumes that the operator has those mechanisms implemented. This will make it even harder to replicate the attack with a commercial purpose,”

Ultralight Attack

In September 2012 a security consultancy Intrepidus[41] demonstrated at the EU SecWest event in Amsterdam,[42] that MIFARE Ultralight based fare cards in the New Jersey and San Francisco transit systems can be manipulated using an Android application, enabling travelers to reset their card balance and travel for free in a talk entitled “NFC For Free Rides and Rooms (on your phone)".[43] Although not a direct attack on the chip but rather the reloading of an unprotected register on the device, it allows hackers to replace value and show that the card is valid for use. This can be overcome by having a copy of the register online so that values can be analysed and suspect cards hotlisted. NXP have responded by pointing out that they had introduced the MIFARE Ultralight C in 2008 with 3DES protection and in November 2012 introduced the MIFARE Ultralight EV1[44] with three decrement only counters to foil such reloading attacks.

4.5 Considerations for systems integration

For systems based on contactless smartcards (e.g. public transportation), security against fraud relies on many components, of which the card is just one. Typically, to minimize costs, systems integrators will choose a relatively cheap card such as a MIFARE Classic and concentrate security efforts in the back office. Additional encryption on the card, transaction counters, and other methods known in cryptography are then employed to make cloned cards useless, or at least to enable the back office to detect a fraudulent card, and put it on a blacklist. Systems that work with online readers only (i.e., readers with a permanent link to the back office) are easier to protect than systems that have offline readers as well, for which real-time checks are not possible and blacklists cannot be updated as frequently.

4.6 See also

- RFID
- Physical security
- NFC
- Smart card

4.7 Places that use MIFARE technology

4.7.1 Transportation

4.7.2 Application References

4.7.3 Institutions

- Linkoping university, Sweden - Student/staff ID, access control, library, copy/print, student discount, payments
- London School of Economics - Access control (Unprotected Mifare Classic 1k)
- New College School in Oxford - Building access.
- Imperial College London - Staff and student ID access card in London, UK.
- Cambridge University[102] - Student/Staff ID and access card, library card, canteen payments in some colleges[103]
- University of Warwick - Staff and student ID card and separate Eating at Warwick stored value card in Coventry, UK.
- Regent's College, London - Staff and student ID access card in London, UK.
- Bucknell University - Student ID access card in Lewisburg, Pennsylvania.
- University of New South Wales - Student ID access card.
- University of Alberta - Staff OneCard trial currently underway.
- Northumbria University - Student/Staff building and printer access.
- City University of Hong Kong - Student/Staff building, Library, Amenities Building.
- Hong Kong Institute of Vocational Education - Student ID card, attendance, library, printers and computers access.
- University of Bayreuth - Student ID card and canteen card for paying.
- University of Ibadan, Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- BOWEN University,Iwo, Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Afe Babalola University, Ado-Ekiti, Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Achievers University, Owo, Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Adekunle Ajasin University, Akungba, Ondo State, Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Auchi Polytechnic, Auchi, Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- University College Hospital, Ibadan (UCH), Nigeria - Student ID card and Staff Attendance.(Solutions Colony Ltd)
- Federal University of Technology, Minna, Niger State (FUTM), Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Benson Idahosa University, Benin City, Edo State (BIU), Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Federal University of Technology, Akure, Ondo State (FUTA), Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Covenant University, Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Lead City University, Nigeria - Student ID card and Examination Verification and Attendance.(Solutions Colony Ltd)
- Hogeschool-Universiteit Brussel, Belgium - Student ID card, canteen card for paying, library and building access.
- Southampton University - Student ID card, library and building access - Mifare Classic 4K.
- Delft University of Technology, Netherlands - Student/Staff ID card, staff coffee machines, lockers, printers and building access.
- Dresden University of Technology, Germany - Building access, canteen card for payment
- Chemnitz University of Technology, Germany - Student ID card
- Leipzig University, Germany - Student ID card, canteen card for payment
- Freiberg University of Mining and Technology, Germany - Student/Stuff ID card, building access, canteen card for payment
- University of Jena, Germany - Student/Staff ID card, building access, canteen card for payment

- Technical University of Denmark, Denmark - Student ID card, building access
- University of Duisburg-Essen, Germany - Student/Staff ID card, library access, canteen card for payment
- Disney Infinity - figure and power disc bases
- Walt Disney World Resort - used for tickets, Disney Dining Plan, and room key access
- University of Northampton - Car park access, building access - Mifare Classic 1K.
- Assumption University (Thailand), Thailand - Student/Staff ID card, library and computers access, canteen, transportation and parking payment, election verification - Mifare Classic 4K

4.8 References

[1] MIFARE (2009-12-18). "The success of MIFARE".

[2] "nfc tags". nfc-phones.org. Retrieved 5 August 2012.

[3] "nfc tags". Retrieved 11 August 2013.

[4] http://www.mifare.net/files/8413/5167/2490/MIFARE_Ultralight_EV1_.pdf

[5] Some ISO/IEC 7816−4 commands are used by MIFARE DESFire EV1, including a proprietary method to wrap native MIFARE DESFire commands into a ISO/IEC 7816 APDU.

[6] "German Researchers Crack Mifare RFID Encryption". *Slashdot*.

[7] "Security of MF3ICD40".

[8] http://www.mifare.net/index.php?cID=3119

[9] "NXP introduces new security and performance benchmark with MIFARE Plus" (Press release). NXP. 2008-03-10.

[10] https://www.blackhat.com/presentations/bh-usa-08/Nohl/BH_US_08_Nohl_Mifare.pdf

[11] "MIFARE a world of possibilities" (Press release). NXP.

[12] http://www.telecompaper.com/news/siemens-and-mikron-agree-licensing-deal-$-$22439

[13] http://www.infineon.com/cms/en/corporate/press/news/releases/2007/INFAIM200711-015.html

[14] http://news.cnet.com/2100-1001-204306.html

[15] http://www.smartcard.co.uk/members/newsletters/1998/feb98.pdf

[16] http://www.nxp.com/news/press-releases/2008/11/renesas-and-nxp-announce-licensing-agreement-on-mifare-contactless-technology.html

[17] http://www.gemalto.com/press/archives/2010/2010-11-25_NXP_Gemalto_MIFARE_License_en.pdf

[18] http://www.nxp.com/news/content/file_1818.html

[19] "MIFARE Classic 1K specification". 2009-02-22.

[20] Karsten Nohl homepage at the University of Virginia

[21] Nohl, Karsten; Henryk Plötz. "Mifare: Little Security, Despite Obscurity". Chaos Communication Congress.

[22] Nohl, Karsten; David Evans (2008-08-01). "Reverse-Engineering a Cryptographic RFID Tag". *Proceedings of the 17th USENIX Security Symposium*.

[23] Radboud University Nijmegen Digital Security

[24] Digital Security Group (2008-03-12). "Security Flaw in Mifare Classic". Radboud University Nijmegen.

[25] "Proxmark". Retrieved 2011-01-25.

[26] "Dutch Page". Retrieved 2012-03-24.

[27] Arnhem Court Judge Services (2008-07-18). "Pronunciation, Primary Claim". Rechtbank Arnhem.

[28] "Judge denies NXP's injunction against security researchers". The Standard. 2008-07-18. Retrieved 2010-02-13.

[29] "mifare.net :: Security". Retrieved 2011-01-25.

[30] Webside id-nee: Preparations continue as normal, visited 7 July 2012

[31] Webwereld: New OV chip prevents fraude, 6 October 2011. Visited 7 July 2012

[32] Courtois, Nicolas T.; Karsten Nohl; Sean O'Neil (2008-04-14). "Algebraic Attacks on the Crypto-1 Stream Cipher in MiFare Classic and Oyster Cards". Cryptology ePrint Archive.

[33] Garcia, Flavio D.; Gerhard de Koning Gans; Ruben Muijrers; Peter van Rossum, Roel Verdult; Ronny Wichers Schreur; Bart Jacobs (2008-10-04). "Dismantling MIFARE Classic". 13th European Symposium on Research in Computer Security (ESORICS 2008), LNCS, Springer.

[34] Garcia, Flavio D.; Peter van Rossum; Roel Verdult; Ronny Wichers Schreur (2009-03-17). "Wirelessly Pickpocketing a Mifare Classic Card". 30th IEEE Symposium on Security and Privacy (S&P 2009), IEEE.

[35] Third and fourth bullet points under "MIFARE Classic vulnerabilities" at http://mifare.net/security/mifare_classic.asp

[36] Courtois, Nicolas T. (2009-04-28). "Conditional Multiple Differential Attack on MIFARE Classic". Slides presented at the rump session of Eurocrypt 2009 conference.

[37] Courtois, Nicolas T. (2009-07-07). "The Dark Side of Security by Obscurity and Cloning MiFare Classic Rail and Building Passes Anywhere, Anytime". In SECRYPT 2009 - International Conference on Security and Cryptography, to appear.

[38] Courtois, Nicolas T. (2009-05-04). “The Dark Side of Security by Obscurity and Cloning MiFare Classic Rail and Building Passes Anywhere, Anytime”. IACR Cryptology Preprint Archive.

[39] http://www.iacr.org/workshops/ches/ches2011/presentations/Session%205/CHES2011_Session5_1.pdf

[40] http://www.mifare.net/links/news/update-on-mifare-desfire-mf3icd40/

[41] http://intrepidusgroup.com

[42] http://eusecwest.com/agenda.html

[43] http://www.youtube.com/watch?feature=player_embedded&v=-uvvVMHnC3c

[44] http://www.mifare.net/products/mifare-smartcard-ic-s/mifare-ultralight-ev1/

[45] http://www.nxp.com/news/press-releases/2013/01/nxps-mifare-deafire-selected-to-support-vancouvers-green-city-plan.html

[46] http://www.translink.ca/en/Fares-and-Passes/Compass-Card.aspx

[47] http://www.efesur.com.ar/

[48] http://www.sube.gob.ar/

[49] “Adquisición de un Sistema de Bicicletas Públicas para Rosario” (PDF). *Proyecto de Transporte Sostenible y Calidad del Aire - Secretaría de Transporte del Ministerio del Interior y Transporte a través de la Unidad Ejecutora de Proyecto (UEP)*. 2013. Archived from the original on 2013.

[50] http://www.etr.gob.ar/

[51] http://www.adelaidemetro.com.au/ticketing/metrocard

[52] LOT ltd. “Integrator’s web site (subway solutions)".

[53] http://www.metrobus.com/mcard.asp

[54] http://www.metro-valparaiso.cl/viaje-en-metro/medios-de-pago

[55] http://www.tarjetabip.cl

[56] http://www.cd.cz/

[57] http://www.hsl.fi/EN/ticketsandfares/ticketsontravelcard/Pages/default.aspx

[58] http://ttc.com.ge/?lang_id=ENG&sec_id=155

[59] Triple RFID card-scan, scanned and retrieved: 19 September 2012

[60] https://www.sii.bz.it

[61] Enotna mestna kartica URBANA

[62] Resekortet i Sverige AB. “RKF-specifikationen - Svensk Kollektivtrafik”.

[63] Contactless Smartcard Technology Needs More Security

[64] SmartTech Production. “Card Manufacturer - NXP Mifare Golden Partner”.

[65] http://www.nfctimes.com/news/transport-london-discard-mifare-classic-seeks-desfire-sims

[66] Breezecard homepage

[67] http://www.eetimes.com/document.asp?doc_id=1276540

[68] http://clippercard.com/

[69] http://www.smartek.ru/en/solutions/afcs/afcsprojets/mosmetroafcs.aspx

[70] http://www.mifare.net/en/aboutmifare/news/multi-application-mobile-ticketing-based-mifare-technolo/

[71] http://www.apsparking.com/project-specific.aspx?title=cork-university-hospital

[72] http://nxp-rfid.com/nxp-enables-mobile-ticketing-for-smart-mobile-devices/

[73] http://www.avmm.es/c/document_library/get_file?uuid=ec899839-1020-4680-955d-cb7d9d1c1e46&groupId=16203

[74] https://www.shellsmart.com/smart/index.html?site=en-en

[75] http://www.positivecard.com.tr/

[76] http://www.orik.lk/news_and_press.php

[77] http://secureidnews.com/news-item/dubai-ask-renews-agreement-for-citys-multimodal-ticketing-system/

[78] http://www.nfc.cc/tag/car2go/

[79] http://calllock.com/en/menu1/Solutions/

[80] http://www.techpro.vn/en/news/news/476-nestle-completes-electronic-security-installation.html file:///C:/Users/nxp68019/Downloads/security-update-1-2012.pdf

[81] http://saltosystems.de/index.php?option=com_content&task=view&id=365

[82] http://www.rfidjournal.com/articles/view?10036/2

[83] http://www.godrejlocks.com/godrej/godrejlocks/Pdf/cambridge.pdf

[84] http://www.ox.ac.uk/enewsletters/aad_news_alert/student_administration_and_services/25_06_12_new.html

[85] http://www.rfidsolutionsonline.com/doc/1-fc-kln-implements-philips-chip-technology-f-0001

[86] http://www.siemens.com/innovation/apps/pof_microsite/_pof-spring-2014/_html_en/sports-facilities.html

[87] http://www.mifare.net/en/aboutmifare/news/new-smart-card-solution-scotland/

[88] http://www.mifare.net/en/aboutmifare/news/berlins-libraries-implement-rfid-modernization/

[89] http://www.mifare.net/en/aboutmifare/news/nxp-and-bank-mega-enhance-customer-experience-with-multi-applica/

[90] http://www.muzekart.com/tr/muzekart

[91] http://www.rfidjournal.com/articles/view?3985

[92] http://www.carrotrewards.co.th/ http://www.free-press-release.com/news-new-rabbit-card-brings-e-money-system-to-bangkok-1339744796.html

[93] http://www.nxp.com/news/press-releases/2011/12/nxp-and-bank-mega-enhance-customer-experience-with-multi-application-smart-card-solution-for-in-door-theme-parks.html

[94] http://www.nfctags.com/nfc-applications-which-tag

[95] http://www.mifare.net/files/7113/4978/9303/NXP_JCOP.pdf

[96] http://www.cn.nxp.com/documents/literature/75015874.pdf

[97] http://www.vingcardelsafe.com/en/vce/VingCardElsafe/Products/?productId=604980

[98] http://www.nxp.com/news/press-releases/2012/10/yeldi-group-selects-identive-and-nxp-for-launch-of-first-major-mobile-nfc-cashless-payment-solution-in-india.html

[99] http://www.passolig.com.tr/

[100] http://www.nxp.com/news/press-releases/2009/01/moscow-metro-the-world-s-first-major-transport-system-to-operate-fully-contactless-with-nxp-s-mifare-technology.html

[101] http://www.mifare.net/index.php?cID=3180

[102] http://www.cl.cam.ac.uk/local/wgb/securityaccess.html

[103] http://www.clare.cam.ac.uk/academic/handbook/food-drink.html

4.9 Further reading

- Dayal, Geeta, "How they hacked it: The MiFare RFID crack explained; A look at the research behind the chip compromise, Computerworld, March 19, 2008.

4.10 External links

- Official website
- 24C3 Talk about MIFARE Classic Video of the 24C3 Talk presenting the results of reverse engineering the MIFARE Classic family, raising serious security concerns
- Presentation of 24th Chaos Computer Congress in Berlin Claiming that the MIFARE classic chip is possibly not safe
- Demonstration of an actual attack on MIFARE Classic (a building access control system) by the Radboud University Nijmegen.

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4.11.1 Text

- **Smart card** *Source:* http://en.wikipedia.org/wiki/Smart_card?oldid=632175354 *Contributors:* AxelBoldt, Mav, Amillar, Sabre23t, Nate Silva, Ray Van De Walker, Heron, Olivier, NTF, Edward, Patrick, Michael Hardy, Wshun, Haakon, Mac, Jpatokal, Ahkitj, Samw, EdH, Lee M, Scanos, Mulad, Novum, Crissov, Reddi, Fuzheado, Zoicon5, Jburati, David.Monniaux, Phil Boswell, Robbot, RedWolf, Altenmann, Greudin, Wanawit, Nurg, Roscoe x, Jondel, Christopherwoods, Wereon, Tobias Bergemann, Giftlite, B7342, DavidCary, Jyril, StevenS757, Dinomite, Tom harrison, Elryks, Bobblewik, Edcolins, Mgream, Ran, Juntung, Beland, Mako098765, Wehe, Stobs, SimonLyall, Gscshoyru, Paparodo, Gleam, Fg2, Sonett72, Daevatgl, Maikel, Imroy, Pmsyyz, Cfailde, Gejigeji, ArnoldReinhold, Gronky, Violetriga, Evice, Mwanner, The bellman, Joaocastro, WhiteTimberwolf, Agoode, BrokenSegue, Polluks, Logariasmo, ClementSeveillac, Zachlipton, Andrewpmk, Lee S. 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Johnson, Kasirbot, Widr, JordoCo, Blueviper99, Nobody118, Iskhak956, Helpful Pixie Bot, 2nightingale, Eleventh1, TEXHNK77, Dc352, BBCLCD, AdvancedSmartcardTechnology, Sindhu123, Chmarkine, Tigran Hovsepyan, Armandobasile, Jay.weigall1, TheJJJunk, Jamshaidshaikh, EagerToddler39, Prince Doebler, Cheolsoo, Mac Smart Card, The Anonymouse, Faizan, Alan, Fduchatelet, Lfdder, Sms1sms1, Monkbot, A8v, Swiminpolo, Christilden and Anonymous: 604
- **Oyster card** *Source:* http://en.wikipedia.org/wiki/Oyster_card?oldid=632031695 *Contributors:* Caltrop, Roybadami, Edward, SGBailey, Tompagenet, Ahoerstemeier, DavidWBrooks, Arwel Parry, Jdforrester, Scott, Kierant, Maximus Rex, Morwen, Ed g2s, Nabeel, Chrism, Moondyne, Nurg, Henrygb, Timrollpickering, Sheridan, J.Rohrer, Superm401, Andy, Ringbark, Bobblewik, Tagishsimon, Gugganij, Isidore, Pinnecco, Saxsux, Woggly, 159753, Mgream, Juntung, Beland, Nzseries1, Hammersfan, Histrion, MRSC, Darksun, Frankieroberto, GreenReaper, Adashiel, Zoganes, Grstain, Chris j wood, Discospinster, Rich Farmbrough, Naive cynic, ArnoldReinhold, Andrewblack, Geoking66, DS1953, Tom, AnyFile, Rje, Sam Korn, Pharos, Jumbuck, Sully, Rd232, Andrew Gray, Mailer diablo, Saga City, ProhibitOnions, Dtcdthingy, Tony Sidaway, Geraldshields11, Gingerblokey, Thryduulf, Boothy443, Youknowyouloveit, Pol098, Brentdax, Prashanthns, Mandarax, DavidCane, PinkPig, Rjwilmsi, Tawker, Miserlou, SimonMenashy, AlisonW, NRTurner, PkerUNO, SchuminWeb, Anskas, Barrykas, Eyebee, Aslate, Penguin, Kellergraham, Benlisquare, Jared Preston, Tonync, Staticfish, Rapido, TFoxton, Eraserhead1, Pip2andahalf, Lincolnite, Jenks1987, Wiki alf, Jaxl, Bossrat, Nick, RFBailey, Nate1481, Deckiller, Jdan m, Raysacks, Mattdickinson, Greaterlondoner, Dbratton, Jcrook1987, Bods, Cloudbound, Chase me ladies, I'm the Cavalry, Willkm, Mike1024, Back ache, JLaTondre, Ajuk, Mrdini, Thomas Blomberg, Kingboyk, DVD R W, Version-3-point-1, A bit iffy, SmackBot, Thelem, DOuG, Stifle, Mauls, Marktreut, Seann, Betacommand, Anwar saadat, Achmelvic, Thumperward, JaT, Mdwh, Hgrosser, Sprocketonline, Frap, Shashi verma, OrphanBot, Azumanga1, Kinders, Agschwen, Cybercobra, Jklin, Bob Castle, Deiz, LDHan, Tesseran, Ohconfucius, JLogan, Via strass, Gobonobo, JohnI, Sir Nicholas de Mimsy-Porpington, Joendrup, Fkmd, Martinp23, Peter Horn, Nakedcellist, Cnbrb, Jeppi, Iridescent, Sameboat, Wow fab groovy, Jt spratt, Wikidwitch, Tawkerbot2, M4tth3wg, Lee Stanley, Peeky44, Hamish2k, Spr12ian, Imcdnzl, Jberanek, DanielRigal, Birdhurst, Simply south, Rahulswarnkar, Cydebot, Hydraton31, Future Perfect at Sunrise, MBRZ48, Oosoom, Travelbird, Corcorda, Oxyman42, GetThePapersGetThePapers, Thijs!bot, Epbr123, Vertium, Gamenews6, Ray harris1989, StopBob, AntiVandalBot, WinBot, SummerPhD, Kbthompson, Malcolm, Bliksim, Hassocks5489, Bigjimr, Thundernlightning, Bearly541, Mauritsvink, Boleslaw, Magioladitis, Harvey5150, Tomhannen, Chesdovi, Nick Cooper, Tomcakes, Sirap bandung, Lukecarpenter169, JaGa, Nankai, Ricardv46, Lost tourist, MartinBot, Rettetast, Reggy73, Nono64, AgarwalSumeet, J.delanoy, Pharaoh of the Wizards, Johnnaylor, Henry.nutter, Ivan Scott Warren, AdamMillerchip, Cometstyles, Mirithing, Denham331, B0YC0TT, Andy Marchbanks, Million Moments, Squids and Chips, Donsherio, 28bytes, TreasuryTag, Gottago, JakeMirame, Thomas d stewart, Kevin Steinhardt, Artybrad, Cw23,

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