State of the Art in Electronic Ticketing

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Interner Bericht 2002-7

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WS 2002/2003

ISSN 1432-7864

Contents

1 Introduction

This report is a result of a diploma thesis ([Garc02]) in which a protocol for electronic ticketing in public transport has been developed. During the progression of this thesis we found that it is very hard to access detailed information about the existing protocols and their policies. We explain this by the fierce competition which currently takes place in the field of ticketing with smart cards.

Current ticketing is mostly carried out by simple paper tickets which can be easily duplicated or corrupted. They must be purchased in automatic vendor machines or distribution sites. Because of recent technological developments, new systems are now possible, and as ticketing is a common daily action in most European countries, it is reasonable to think of improving the used infrastructures.

Smart card technology has been shown to be one of the most interesting technologies for ticketing. Physically, a smart card is credit-card sized with an embedded circuit that can provide microprocessor functions like adding, deleting and processing information. These microprocessor powered cards can perform operations that may help to attract the Transport Authorities as customers since they are capable to work out adapted fares individually for each user, to reward loyalty and to include personalized functions. Furthermore, this new concept will also entail long-term savings to the transport companies because at present smart card technology is relatively cheap and it is able to substitute the printed paper tickets with a single chip, enlarging the durability of the transport ticket.

In this report we will not present the protocol developed in the thesis but give a broad survey of the four ticketing policies we were able to identify as well as of the current projects which take place all over the world. To the best of our knowledge such an overview has not been published until now.

2 System Policies

By their characteristics, smart cards have been accepted in different fields to carry out new services which can provide the users with better facilities. They also represent improvements in comparison to the use of paper tickets for public transport. To exploit them, every project has its own policy of fare collection. In general, four types of policies can be distinguished: Electronic Paper Ticket, Check-in/Check-out, Walk-in/Walk-out and Be-in/Be-out. They will be described in this section. Additionally, for each of them some projects will be shortly introduced.

2.1 Electronic Paper Ticket

The Electronic Paper Ticket (EPT) is one of the first approaches towards electronic payment in the public transport with a smart card, an idea not developed enough to exploit the card's whole potential and that mainly tries to adapt the current system of paper tickets to a smart card without changing the notion of the payment system.

They benefit from the fact that cash is not necessary to acquire tickets since the card can be charged through a bank account, and the speed of ticketing increases considerably if contact-less cards are used. They offer the advantage that it is not necessary to spend money on printing physical tickets since they are uploaded onto a single card. Furthermore, they also benefit from non-cash handling in the charging process.

On the other hand, travel fares in this EPT policy are set as nowadays by dividing the city into zones. The price of one ticket does not depend exactly on the travel distance. Within one zone, it does not matter if a user leaves the vehicle at the first stop or at the last zone-stop. The price for one ticket for one given zone is fixed. Traveling through several zones may cause considerable price discrepancies if the user leaves at the first station of the last zone instead of at the last station of the previous zone.

One of the advantages of this system is that informations on the travelers' behaviors, although limited, are gathered and can be stored in databases. This is valuable for marketing purposes. The system also benefits from smart card multi-application properties like using the same card for e-purse or for parking payments (park and ride). These new features make the EPT more interesting in comparison to the real paper ticket. But the lack of automated fare collection (AFC) causes a considerable disadvantage.

The charging of the cards is performed at the travel sector machines located near the stops called POS (Point Of Sale), in the transport vehicle or at the central transport office. In any case, the user inserts the card and performs the payment either with cash or with credit card. Some of the projects like intermobilPass [Proj99] in Dresden, Germany, come to an agreement with the banks to give the possibility to link the account of the user to the card. That way, the user can use the card as an e-purse and buy the tickets without needing cash or credit card. This also provides the possibility to charge the card in the automatic teller machines (ATM) from the user's bank.

When performing the ticketing, the passenger just inserts this transport card in the reader or in case of contact-less systems, passes it in front of the device within the required distance insuring a correct processing. The system checks the validity of the card, the amount of money or the valid tickets stored on it and carries out the respective operations.

In case of a non-valid card, the authentication is not performed and an error is displayed. The same happens if the amount of money or the tickets on the card are not sufficient for the trip. The user may then either charge the card or leave the vehicle.

The handling of zones of the system is performed in several ways depending on the project. In some cases, the reader besides its display, has an input device that enables the user to select the travel he is going to make. Some others projects like Sirocco (see [PeHe02],[PeHe99], [Paya99]) in Barcelona, Spain, allow the user to preselect a ticket stored in the card which will always be chosen as default for a travel. In other systems this selection is performed by the driver like in the project *Ab und Zu Karte* [OVA 01] in Aalen, Germany.

Once the user has performed the check-in operation, some data is stored in the card that could show an inspector the validity of the payment. These data remain stored for a period of time after which it is no longer valid. The inspector in this system needs a device capable to read the information on the card and to check its validity.

This policy still uses period tickets (e.g. six months ticket, monthly ticket, weekly ticket) which are also stored into the card. Some projects have special cards for these passes like for example a monthly card that has to be updated every month and that can only be used for the zone it was bought for, that is the case of BNV-Card [Ove] in Biberach, Germany. Some other projects store a special ticket into the card, which can be used together with other single tickets.

Special fares are also handled by different cards or are digitally controlled by the charging machine. In such a case the user needs digital identification as for example another smart card or magnetic stripe card readable by the system. This information can be stored in the card in case the user personalizes it.

2.2 Check-in/Check-out

When the power of smart cards got generally known, the companies implemented more elaborated solutions as for example the Check-in/Check-out policy also known as CICO. This policy is the first which makes use of the idea of automated fare collection (AFC) where the system calculates the fare for the trip on the basis of time and distance.

The smart card does not behave as a purse anymore and the costs for one trip is not known in advance. The basic idea of the CICO policy, is to insert the smart card twice, once when entering the vehicle and then when leaving it. At the entrance, a check-in is performed where some data like date and time, vehicle identifier or stop identifier are stored in the card. Stop identifiers are the numbers used to differentiate the vehicles from the system. When leaving the vehicle and performing the check-out, the card transmits this information to the system which calculates the respective fare and deducts the cost.

The projects perform different variations from this policy to reward the passenger, like for example the system *Octopus* [Octo94] in Hong Kong, China, where the fares are cheaper in non-rush periods of transit.

To allow for loyalty rewards other systems, like *get-in* [Rheia] in Hanau, Germany, store the information up to one year. Thus, as time goes by, the travels made are memorized providing informations to benefit from special fares such as those for periodic tickets. Under this option, the user receives a monthly invoice where all the trips and their prices, possibly discounted, are detailed. Within this system the card must be personalized and linked to a bank account.

Special fares are handled through special cards, for instance for children or students where the calculation of the fares is different. The purchase of these cards can be done in the transport central office and requires to prove the identity of the person which is going to use it.

The inspection of the tickets is performed again with a smart card reader with which the controller checks the validity of the check-in procedure.

In the EPT policy, the system knows immediately if the user's card is able to perform the ticketing, but in CICO policy this is more complex. This is due to the possibility of considering several fares. In particular, when riding different vehicles is required to reach a destination. In this case there are several fares and it is impossible to decide in the check-in procedure whether the balance left on the card is sufficient for the entire travel. Normally, the user is allowed to execute the check-in while the balance is still positive although in some systems the minimum or maximum price for a ticket is considered to permit the entrance of the passenger. When the price to pay for the trip at the check-out exceeds the balance of the card, most systems allow a negative balance urging the user by means of information on the terminal display to charge the card before traveling again. Another system, *i.Ti.* [Verk99] in Bonn/Köln, Germany, does not allow the check-out if the card is not sufficiently charged and therefore, the user should check in advance the balance and charge it inside the vehicle if necessary.

In order to avoid system frauds, the check-in is only permitted with a previous check-out. In systems like *i.Ti.*, during a check-in it is checked whether there remains any active travel, which means the previous check-out was not properly performed. In that case, the device performs the check-out for the previous ride (with time and distance data stored in the card) and a check-in for the current ride. Systems like *get-in* [Rheia] in Hanau, Germany, detect the not performed check-out and penalize the user with an amount of money equivalent to the maximum fare.

In the Check-in/Check-out policy, the information about the stops where the user could enter or leave, is not sufficient. The system also needs to know the time the user spends in the vehicle to forbid users to complete a circle journey at zero cost. For example if the user decides to leave the vehicle without making the check-out and enters the same vehicle afterwards without making the check-in, he would have a valid ticket without paying the correct cost.

The card can be recharged in the same way as the one described in the previous section (EPT). It is also possible to receive an invoice as explained for the *get-in* system in Hanau.

With this policy, transport companies benefit from the information obtained in their databases for marketing purposes as it happened with the electronic paper ticket, but they have additional information about where the users enter the vehicle and where they leave it. This enables them to gain a more reliable reality model and thus to a more efficient management of their network.

Since CICO uses similar infrastructures than those in EPT, this system requires similar management and design costs but contributes more advantages for both the users and the transport companies.

2.3 Walk-in/Walk-out

The ticketing policy Walk-in/Walk-out, WIWO, is an even more innovative policy than the ones presented previously. It is proposed by the Swiss project *EasyRide* [GyDe01] and it is carried out in the region of Geneva pending to be fully operative in the year 2008.

The basic idea is similar to the CICO policy: the fares are calculated taking into account the time and distance the user spends in the vehicle. But WIWO is based on the *walk* of the user in and out of the vehicle. This means the user would not have to *check* neither *in* nor *out* at the terminal device.

The main idea is the use of two antennae in each entrance of the vehicle, which create two magnetic fields capable to activate the card and perform the ticketing. They switch the card from its sleep status to its active status permitting the exchange of information. Swatch-EM Marin-Hayek Consortium has especially designed the card used in this system and it is capable to establish an active communication with the system due to an embedded battery.

To establish communication the card only needs to be situated in a magnetic field. Even if the user does not draw it, the check in/out is performed. Within this system the user is not the only one who benefits of the advantage not having to unpack the card every time a check-in or a check-out must be performed, but also the transport companies can be almost sure that if the user takes the card with him the checking is performed. A conductor is still needed to prevent from traveling without or with a “protected” card (e.g. transported in a metal box).

The antennae radiate at the same frequency creating two magnetic fields that send different informations. In the first magnetic field, A, the station’s identification number and the antenna identifier are transmitted. The second magnetic field, B, transmits the vehicle identifier, date and time together with the B’s identifier. Therefore, as a person enters the vehicle, the antenna identifiers constitute the combination A.B which will be interpreted by the system as *IN* while if the passenger leaves the vehicle, the combination will be B.A and identified as *OUT*. In this way, the system *knows* whether the user is entering or leaving the bus. Further on, this flow of information will be called ticket-data.

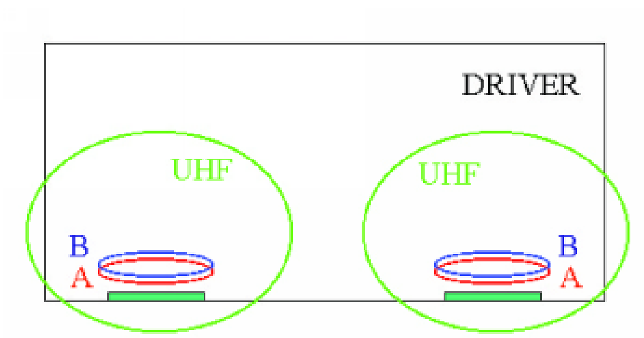

Figure 1: WIWO Policy in Geneva

There is also a high frequency field which covers a greater area than the fields generated by the antennae A and B, used for the communication between the card and the on-board readers. In this communication, the card identifier and its internal status (IN or OUT) together with the ticket-data are transmitted from the card to the on-board computers being inserted in the local database of the vehicle. At regular intervals, the information contained in the local database is transmitted via GSM to the central public transport database of the system where it is then processed.

A description of the system is presented in figure 1 where the magnetic field A is represented by a red ellipse and the magnetic field B is colored in blue. Those fields are located at the entrances of the vehicle. Once the user goes through these two fields, the card is activated without the need of drawing it and receives the ticket-data from the system. Going through the fields from A to B, the combination of antennae identifiers registers in the card the status *IN*, or *OUT* if the user goes from B to A. The green ellipse represents the Ultra High Frequency (UHF) magnetic field through which the system exchanges the ticket-data with the card storing it in the local database. As soon as the system receives the information it sends an acknowledgment response signal and the card returns to standby mode.

The card is designed to store up to 200 entries of ticket-data that could be later viewed by the user through *EasyRide* special devices. In comparison to the other projects (except for *get-in*), this one only works with a periodical billing. That means the user does not have to charge the card. In most cases, a passenger obtains a smart card identifier only once for an unlimited number of journeys. This identifier is linked to his bank account and the user is billed periodically with an invoice containing all the data from her/his travels. As in the *get-in* project [Rheia] the system applies different fares in relation to the travels made to reward the users loyalty.

Since not all the public transport users may have a card (e.g sporadic users like tourists), the system still allows the use of conventional paper tickets, but for example in *EasyRide* discount and bonus schemes are not available.

The ticket inspection is made by checking whether the card has been registered on boarding, and if it is still valid or non-blocked. This inspection does not require to insert the card in a device because the controller device can communicate with the card and get the information by a radio frequency, similar to the communication between antennae and card.

The system also handles specific problems such as for example the possibility that one user remains between the two fields to avoid payment. It prevents this situation to occur by switching the magnetic fields at each stop. While the doors are closed, the A-zone becomes B-zone for a short period of time and the other way around, before the doors are opened, the B-zone becomes the A-zone for a short period of time and thus performing the check of the card.

It should be remarked that repeating entry and exit registration at the same stop is combined as a single internal message within the system. This does not add any additional data to the card or the database, for instance when someone helps carrying a luggage inside the vehicle.

2.4 Be-in/Be-out

The same project, *EasyRide* [GyDe01], surveyed in 2.3, implements another policy to handle payment. This policy Be-in/Be-out, BIBO, is in fact carried out in Geneva and Basel following two different schemes.

The BIBO policy implemented in Geneva works as WIWO, with two low frequency magnetic fields at the entrance (A and B), but differs in the fact that the high frequency field (UHF) is created by three readers covering not only a part of but the entire vehicle. After the first registration step, passing through the A and B magnetic fields, the card remains in a medium power mode of operation. It regularly transmits a signal containing the ticket-data mentioned in the WIWO policy throughout the journey to the on-board reader.

In a basic implementation of this model, the Low Frequency (LF) fields A and B are not strictly necessary. The system uses them to activate the card is thus able to distinguish the users inside the vehicle from those who are simply passing nearby. To simplify the implementation, the system only uses one LF-field, although this cancels the possibility of direction detection.

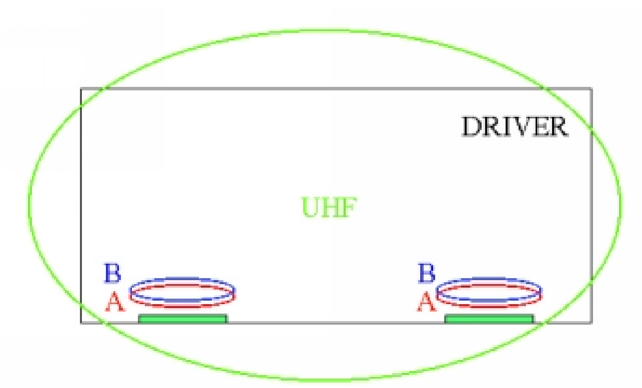

Figure 2: BIBO Policy in Geneva

In figure 2 a scheme of this policy is presented: The LF fields are represented as in WIWO policy, with the colors red for the A magnetic field, and blue for the B magnetic field. In this case, the HF field, represented by the green color, covers the entire vehicle, and the transmission will take part periodically during the journey.

BIBO policy in Basel offers a remarkable difference in comparison to others. Instead of two different magnetic fields at the entrance, it has an activation field that covers a radius of 3 m at the entrance of the vehicle. This field activates the card. After one card is activated, it communicates with the on-board readers through an Access Point (AP) located inside the vehicle between stops. This magnetic field created by the AP covers the entire vehicle, transmitting the ticket-data periodically. If a user enters and leaves the vehicle at the same stop no data is transmitted even if the card has been activated. The card is activated again when the user leaves the vehicle.

Figure 3 represents the operation mode of this policy. The activation field represented in blue covers the entrance activating the card. The Access Point situated in the middle of the vehicle radiates the HF field which maintains communication with the card periodically during the journey. This system is better adapted to vehicles like trains, which have an entrance area.

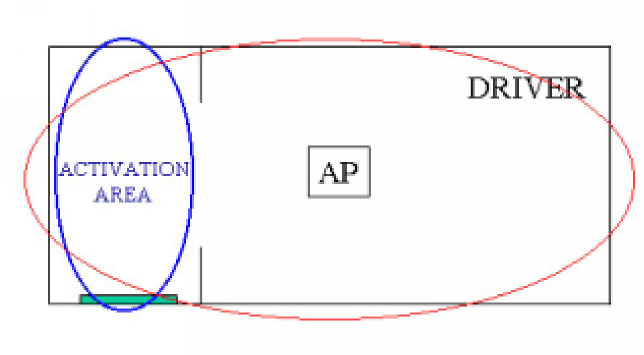

Figure 3: BIBO Policy in Basel

The card used in both projects BIBO from Basel and Geneva, is the same as the one used in WIWO policy, designed by Swatch-EM Marin-Hayek Consortium. With the embedded battery, the card is able to stay in a passive mode until the activation signal awakes it to the active mode. Its intelligence enables it to use both BIBO and WIWO modes simultaneously.

The main advantage of these BIBO policies versus WIWO is that the process algorithms and infrastructure installations are simpler. Furthermore, the registration is performed periodically inside the vehicle so the error handler must not be as complex as with the WIWO protocol and the installations can be reduced to one antenna generating a global magnetic field. A disadvantage is the non-optimized power consumption of the BIBO policy, because the card has to send information periodically.

As well as in WIWO policy, the vehicle's position is detected with the GPS system and the data is transferred via GSM from the on-board computers to the central computing center.

For the people without card paper tickets will be still available but discounts cannot be applied. Moreover, the inspection of a valid payment is carried out as in WIWO policy.

3 Projects

To illustrate the protocols briefly described in the previous section, it is suitable to show some exemplary projects. It is then easier to understand how they operate. In the first section the *SIROCCO* project [PeHe02] implemented in Barcelona, Spain will be described with the policy EPT. Next, there is an example of the Check-in/Check-out policy with the project *Octopus* [Octo94] in Hong Kong, China and at last the implementation of WIWO and BIBO policies by the *EasyRide* project [GyDe01] in Switzerland.

3.1 SIROCCO

As an example of Electronic Paper Ticket policy, the *SIROCCO* project ([PeHe02],[PeHe99],[Paya99]) is explained in this section. It has been developed in Barcelona (Spain) by the transport company FGC (Ferrocarrils de la Generalitat de Catalunya) using a CombiCard, which allows the user to use contact as well as contact-less interfaces.

In this policy the smart card provides ticketing and e-purse applications, therefore, it contains virtual money and transport tickets. These transport tickets are denoted as "Titles", and the card is called Transport Purse Card (TPC).

Gemplus [CaHu02] supplies the cards for this project with the GemCombiWG10 CombiCard operative system following the norm ISO-7856 [Int]. Their storage capacity varies from 2K up to 8K bytes and contains logs and secret keys that comply with WG10 European banking security standards for both e-purse and ticketing applications.

The users can choose between personalized and anonymous cards. The project is developed in conjunction with the bank "Banc Sabadell" [Banc] and therefore if the user chooses to personalize his card, it will be linked to his account at this bank. In figure 4, there is a scheme with the connections between the bank and the operations permitted by the card. The user can charge the card by means of the bank Automatic Teller Machine (ATM) with the financial environment "4B" and in other POS like ticketing machines or shops. When paying for public transportation, parking areas or when using other e-purse applications the information on the transactions is stored in a central database of the bank.

Anonymous cards have to be charged by cash or by electronic payment systems in the POSs provided by the transport agent FGC. To perform payment the card uses its serial number to sign the transactions and be authenticated by the system. This way the system is able to reconstruct the contents of the TPC in case of its destruction or unreadability, so even when the card is anonymous it is still traceable.

The restricted files are protected by the operating system installed in the card and designed for this project. The security attributes fix the security conditions that shall be satisfied to allow operations on the files. These access conditions are defined for a group of commands, which are different depending on the file one is referring to (EF or DF). The file access conditions can be:

- **Free**, which means the file can be treated without any restriction,
- **Secure Code**, only modifiable if the knowledge of a password has been proven,
- **Locked**, which means the file is never accessible and
- **Secret Key**, only accessible if the terminal proves the knowledge of the secret key; in this case, any operation must be performed in a secure way, sometimes with cipher text.

The system works with a session key for authentication (SKauth) and a key for secure messaging (SKsecure) both of them are 8-bytes random numbers received from the terminal. All the transactions include the following steps:

1. Session key generation, 16 bytes
2. Card authentication signature
3. Terminal authentication signature
4. Transaction authentication signature

The authentication is based on cryptographic signatures and DES. Triple-DES symmetric algorithms are used for the transactions. Each Title file owns 2 cryptographic keys to perform this symmetric encryption: a 16-bytes key used for reloading existing Titles and an 8-byte key used to validate them in the ticketing terminal.

After their implementation in the Issuer's company, in this case Gemplus, the cards are sent to the Banc Sabadell which is responsible for its delivery to the transport company. The user will have to contact the public transport central office to apply for either a personalized or an anonymous card. When applying for a personalized card, the application is sent together with the users data to the 4B financial environment system, which is also responsible for selling the Titles.

Once the user has his own card, he is able to acquire transport Titles from the point of sale terminals, ticketing machines (MAE) of the station or the automatic teller machines (ATM) of the financial environment system 4B (from Banc Sabadell). Occasional travelers have the possibility to pay with an e-purse to acquire single fare tickets.

The uploaded Titles could be single Titles, multi-trip Titles, monthly Titles or annual Titles allowing different zones of travel. The fare depends on the costumer who buys them (normal, student, children, retired people, etc.). Besides the Titles implemented now, the system allows for future changes.

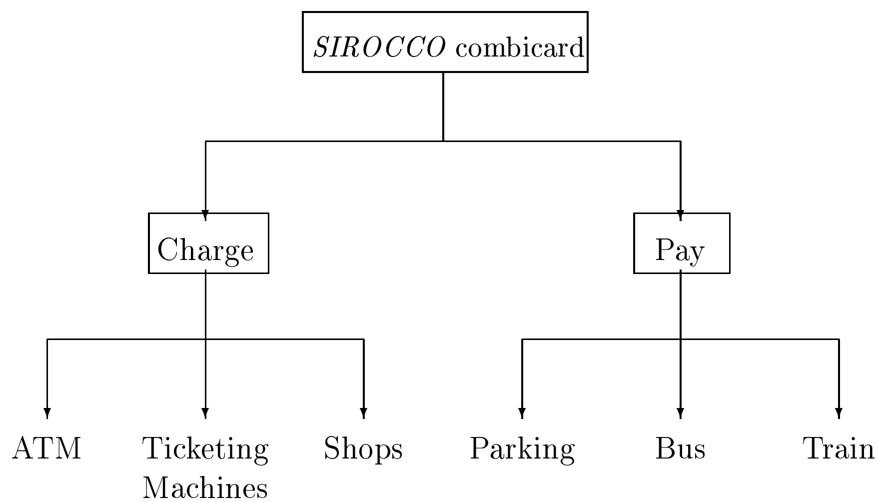

Figure 4: Project *SIROCCO*

The ticketing machines (MAE) are designed to enable various payment modes, but as they only have one reader slot, the card which stores the titles should also be the card which is used to pay for them (only one card can be inserted). A problem arises during the identification process of special fares (students, children or retired people). In that case, digital accreditation must be introduced first, keeping the data in a latent state inside the MAE for its use at the appropriate moment. When inserting the TPC, the MAE will show the Titles included as well as the free Title space (the storage of Titles is limited to three) giving the user the options to upload a new Title, re-charge the existing Titles or change any of them.

The automatic teller machines of system 4B work in a similar way as the MAEs to acquire the Titles. They cannot sale Titles that need accreditation (for special fares), but they offer the possibility to re-charge this kind of Titles if they have been previously granted in FCG MAEs. According to its location, the ATM will display three default Titles (for the zone in which the user is located). If the user needs a ticket that is not displayed, the MAE will contact the central host for further information.

Once the tickets are stored in the card, their cancellation is performed by the contact-less interface of the smart card. When the user approaches the smart card to the reading device during a brief lapse of time, the display of the ticketing terminal shows the information about the process. In the subway, the ticketing terminals are connected to the gateway that will open when the Title is valid.

The Titles stored in the card have different priorities that define which Title is going to be used at the next transaction. These priorities can be changed by means of a new device introduced in the project called "Preselector". The Title stored as "default Title" has the highest priority and it is the one used for the cancellations while the other two ones are designated by first and second Subtitle and are only checked if the default Title is not valid. In case the card does not store any valid ticket, the user is not allowed to get on board.

The use of the Preselector device is a disadvantage in comparison to other projects since the execution of another operation is necessary if the user wants to change the default Title. Furthermore, the speed of boarding gained by the contact-less interface is reduced by this device as it can lead to cause queues of people who want to use it.

The user cancels his tickets at the ticketing terminal. This terminal owns a screen on which the following data are displayed:

- "Terminal out of order" or
- "Terminal is idle" and
  - date,
  - time,
  - error messages (together with an acoustic signal),
  - information about the successful cancellation (=validity) of a Title,
  - after cancellation, in case of a multi-trip Title: number of remaining trips.

A multi-trip Title can be used for several travelers if there are not more than two seconds between two cancellations.

Since it is needed to check the validity of the tickets in order to avoid fraud, the controllers of the travel sector have a portable device which allows them to check the TCPs of the travelers. This device permits to check the active Title in the card as well as the history file that contains the last 10 trips. With this device, the controller may also change the Title selected as default.

The information about cancellations is stored in a central database, which is used to provide statistical data as well as a commercial profile through individualized tracking or by any other means.

After having explained the EPT policy and especially this project, it can be concluded that an EPT policy does not have the advantage provided by an AFC system regarding the pricing policy for tickets. It also lacks the convenience of not selecting the fare previous to the travel, but the advantage is that the user only has to draw the card once per travel. The main difference that can be found between *SIROCCO* and other EPT projects is the use of Titles uploaded to the card instead of selecting the fare before boarding. As a matter of fact this has also to be done if the default ticket has to be changed and therefore, the speed of boarding is only increased when the user always uses his default ticket. The transition from the current system to an electronic system with EPT policy is not very drastic. This is important because adapting the behavior of the user to a new system needs time. Regarding this project, the behavior must not be changed as much as in other projects. The Preselector device is a new idea integrated in this system that may represent a big change in the user's way of thinking about charging and paying for public transportation.

3.2 Octopus

As an example for the Check-in/Check-out policy, the *Octopus* ([Octo94]) project in Hong Kong, China, will be described.

This project has been designed by the ERG Group [ERG], which is devoted to automate fare collection systems. The system uses the Sony Felica contact-less card. Its contact-less interface permits the authentication and ticketing in 0.2 s with a speed of 211 Kbps with an operative range of the reader/writer devices ranging from 3 to 10 cm depending on the model used. Mutual authentication between the card and the reader is based on a secret key system, using the Triple-DES algorithm for authentication and DES algorithm for the communication. These cards contain a RISC architecture based 8-bit CPU as well as RAM, ROM and EEPROM, which varies from 1 up to 4 MBytes of storage capacity.

Octopus is not based on any Titles since it uses automated fare collection provided by the check-in/check-out mechanism. Instead, the user must charge some money at the loading terminals from the travel sector into the card by means of cash or electronic payment systems such as credit card.

Users benefiting from special fares (e.g. students, children and senior travelers), receive special cards which are identified by the charging machines that applies then the relevant fares.

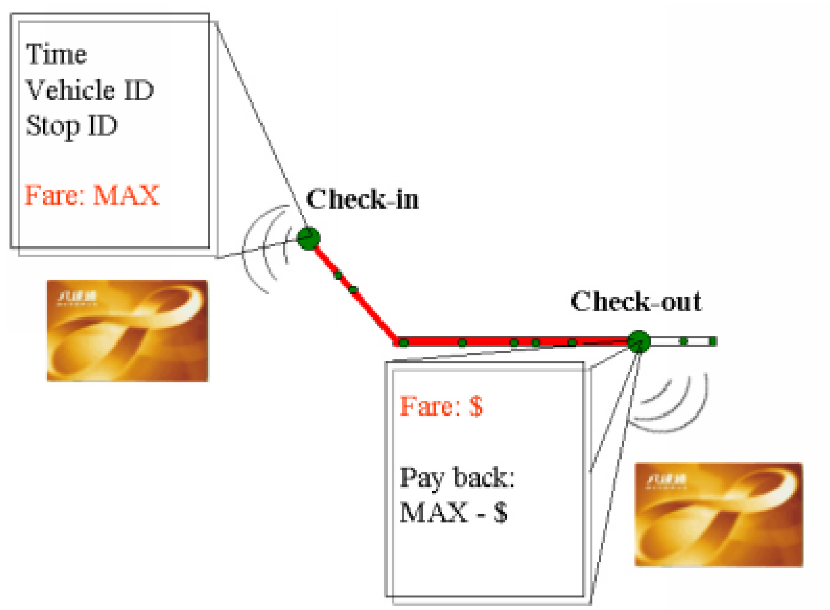

Figure 5: Automatic charge of maximum fare in *Octopus*

The cards can be personalized. Those cards store personal data in the chip and include (optional) the picture of the user printed on it, which makes them not transferable. If the user loses his personalized card, the remaining value stored in the card is credited to the card-holder. Their acquisition can be handled by application forms provided by Internet or transport offices. Discounts are applied to the user in order to reward his loyalty [1] in relation to the number of travels made. The *Octopus* system establishes different fares in relation to the transit; during high transit hours, the tickets cost more than the rest of the day. The users with non-personalized cards do not enjoy the bonus scheme and there is no protection against lost.

To check the remaining credit there are special devices at each station, which display the card's balance as well as the last ten transactions. The system displays the balance on the ticketing terminal every time a user performs either a check-in or a check-out.

With *Octopus*, the ticketing terminals performing check-in/check-out are located outside the vehicle. Before boarding a check-in is performed by passing the contact-less card in front of the terminal and similarly for the check-

[1] Only with personalized cards

out when the travel ends. The system handles different fares for first and second class providing two different ticketing terminals. If the user wishes to travel first class, he should use the processor located on the first class waiting area, which will apply a different fare.

A check-in deducts the maximum possible fare from the card. If the operation is valid, the device displays a green light with a message "permit to travel" emitting a single short audible tone. If the card is invalid or if it does not have enough balance, a reject message with a red light is displayed and the terminal emits a longer tone. When this occurs, the passenger is required to buy a single ticket or to seek assistance in the nearby customer service center.

After alighting, the user passes the card to the exit-processor which rebates the difference to the *Octopus* card after computing the exact fare of the travel. The amount charged as well as the remaining balance of the card are displayed on the terminal with a green light and a double audible tone is emitted. In case of an invalid check-out, the terminal shows a rejecting message with a red light and emits a long audible tone. Not performing the check-out implies the automatic charging of the maximum fare (since it has already been paid for it at check-in). See figure 5 for the fare charging process.

If the remaining cash value of the card is positive but insufficient to perform a new check-in, the user can still use it providing a negative balance that cannot be higher than a previously established limit.

In case of a personalized card, the user can link it to a bank account in one of the banks authorized by the transport company. In that case, the system offers the possibility to apply for the automatic add-value service. This service provides automatic re-charge in three different cases: the balance reaches zero, the balance is negative or the amount left is not enough to pay the check-in [2]. The fare processors perform the transaction charging the card with a fixed amount, which will be detailed in the users bank statement. This action can be performed only once per day.

As well as the new payment system, *Octopus* still provides single paper tickets for sporadic travelers that can be acquired in the ticket issuing machines (POS devices). Furthermore, one and three day passes are still applicable for tourists.

The reader/writer devices are connected to the *Octopus* fare processor, which receives commands from the fare processor controller on the actions to be performed. The data is stored for clearing purpose in the reader or sent back to a host computer, depending on whether the fare processor is on-line

[2] The check-in always costs the maximum fare

or off-line.

Innovations within this project have been achieved recently in collaboration with Junghans [Jung] and Nokia [Noki]. Junghans, a watch company, has embedded the *Octopus* chip in some of its watches permitting the user a new and comfortable way of checking in and out. This chip maintains all the characteristics of the *Octopus* card as for example the personalized services or the special fares. Nokia, a mobile communications industry, has done the same with its mobile phone models 3310 and 3330 installing the chip in their cover.

The idea of CICO is innovative as it uses automated fare collection. Since the payment is realized by contact-less interface, and there is no need to previously select a fare, boarding speed is faster than in an EPT policy. On the other hand, the two-times drawing of the card, may be quite uncomfortable for the users.

3.3 Easy-Ride

The System Easy-Ride [GyDe01] uses two different policies: WIWO and BIBO for the regions of Geneva and Basel. Since both policies use the same technology and infrastructures, the general EasyRide concept will be cleared up in this section.

In WIWO policy as well as in BIBO in Geneva, two low frequency magnetic fields are used at the entrance of the vehicle providing two meter radius operational area. These fields are generated by two antennae, which radiate at 125 kHz with a 3D polarization. They activate any card that goes through their operating range. Since no information must be transmitted from the card in this first phase, the communication is one-way from the reader to the card. See figure 6 for communications flow scheme.

With the purpose of better adapting to the vehicle installation, these antennae can adopt different shapes and sizes, being able to fit in the tubes, bars or even in the walls of the vehicle in their flat version.

The third magnetic field used in those implementations, is the high frequency field. It is radiated by an UHF antenna at 433 MHz with duplex communication since it has to exchange information with the card. In the case of the *EasyRide* project in Basel, information exchange is performed all along the journey.

The card in the system designed by Swatch-EM Marin-Hayek Consortium [Swat], contains a miniature radio communication module which links the user to the system allowing the simultaneous use of both ticketing policies (WIWO and BIBO). The capacity of the card allows the user to store up to 200 information entries with details about the travels. The cards permit a

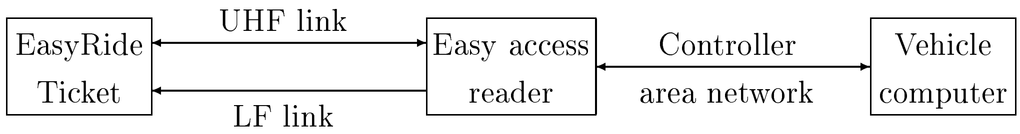

Figure 6: EasyRide access system

capacity extension for future needs. The lifetime of one of these cards, in accordance with the specifications, is two years.

To establish active communication, the card holds a 3-V lithium manganese battery with very low self-discharge. Following ISO specifications [Int] its thickness is not greater than 0.8 mm. Embedded in the card is a low-power, 4-bit micro-controller, which manages the EEPROM storage, LF receiver and UHF transceiver. The micro-controller is a standard product clocked at 600 kHz, whereas, the LF receiver is a specific CMOS low-power, low-voltage design. The UHF transceiver is also a very low-power design. Two antennae are housed in the card.

On-board computers intercommunicate simultaneously with several readers from the same vehicle transmitting the ticket-data information and receiving the data from the card, which may be stored locally. In regular periods, the inputs stored are transmitted via GSM to the company's Central Management System (CMS) at the Head Office. The CMS server summarizes all the received information and transmits the details to the company's Computer Center and Central Application Server (CAS). In the computer center, the ticket-data of every passenger is sorted and analyzed creating profiles of the travelers.

The reader devices carry out the LF transmission to provide the card with the ticket-data (received previously from the on-board computers), which does not take more than one second, and the UHF transmission to supply the on-board computers with the information on the travels.

Personal data like travel informations are stored in a different database to preserve the intimacy of the user, but the billing company has access to both of them since it has to create personalized invoices with the travel details. *EasyRide* still preserves traditional prepaid tickets, which could be considered as an anonymous option, but they do not handle AFC or bonus schemes.

Since the fare resolution is based on the distance traveled, the system uses positioning information provided by its GPS system, where the radiation of the system is 1000 times weaker than the radiation between a mobile telephone and the base station.

In *EasyRide* the convenience presented by the automatic collection of data, which avoids the double-checking while preserving AFC, is remarkable. The user only has to carry the card, and it performs all the operations independently. Furthermore, the user benefits from the fact that he does not have to charge the card because it is linked to his bank account and the payment is done directly.

But these advantages lead to different disadvantages that should be taken into account. Radiation is nowadays a subject of concern because it is not yet proved that it does not affect human beings and therefore, some people are opposed to use such a system. Moreover, the system traces all the passenger movements, and even if the databases are differentiated, the system could get to know all the information on a particular user and thus violate his/her privacy.

4 World Wide Projects

Many travel enterprises are investing in this new technology to renew their travel sector payment systems. The first initiatives started around the year 1989 when the idea of using smart cards for electronic ticketing was introduced by Cubic Transportation Systems [Cubi] and since then all around the world projects emerged. Some of them are already operative in countries like United Kingdom, Germany, France, Australia, Netherlands, South Korea, Spain and China. In figure 7 and figure 8 some of the most important European and world wide projects are mentioned.

One of the first projects that used the contact-less smart card based ticketing was *Octopus* [Octo94]. It started in 1994, and became operational in the year 1997 in Hong Kong. The system was built by AES Prodata [Ove] which is a member of ERG Group [ERG] using the Sony Felica card [Sony] for contact-less payments as described in section 3.2.

The company ERG Group offers automated fare collection systems cooperating also with transit system projects in Manchester and Hertfordshire (Great Britain). The name of the project is *Herts Smart Scheme* using the Philips [Phil] platform for ticketing *MIFARE*. It is based on the EPT policy, is having different cards to handle special fares and is operative since 1997. Another ERG Group project is *Metrebus Card* operative at the moment in Roma (Italy). Metrebus Card uses a combi-card, which stores tickets like the project *SIROCCO* in Spain but it does not have an anonymous option. In San Francisco (USA) ERG group has implemented the project *TransLink* that will start its first phase in 2003. In this project, ERG Group works with Cubic Transportation Systems to develop an EPT solution which uses in the beginning a personalized card. Once the system is completely finished, it

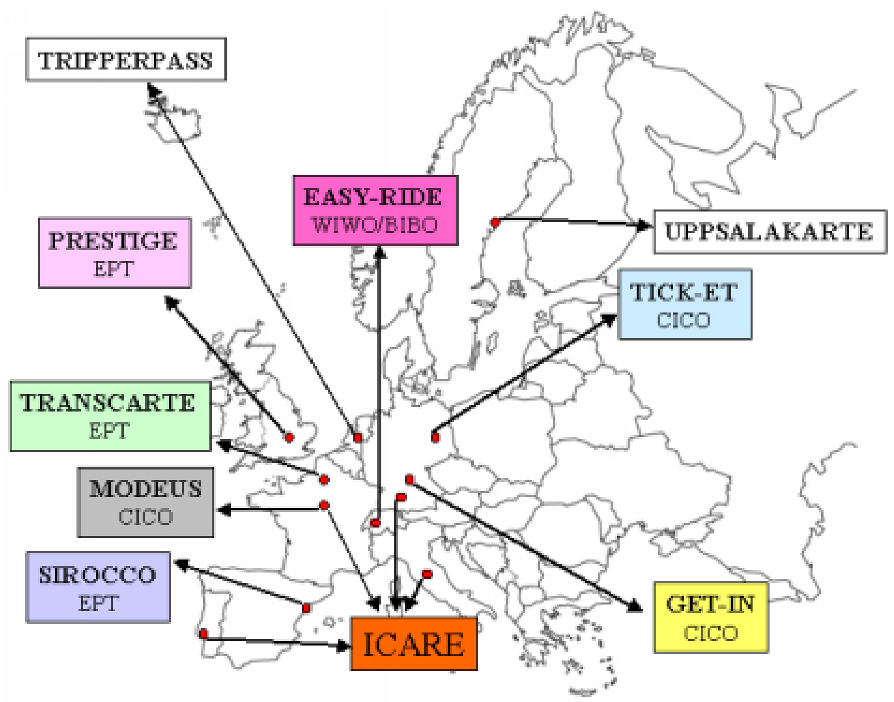

Figure 7: Some E-Ticketing projects around Europe

will handle automated fare collection with a CICO policy. In Singapore a project is reaching the end of its first phase and it is based upon the *LTA Contact-less Smart card* project [Ove]. This project is also developed with the cooperation of Cubic Transportation Systems and performs CICO policy. Lens-Liévin (France) uses the project *Transcarte* operative with a EPT policy since the year 2000. The last project implemented by this company is *Swift Smart Card Scheme* in Wales [Ove].

In 1999 ERG built an alliance with Motorola wining contracts to conduct trials in Berlin (Germany), Sydney (Australia) and Groningen (Netherlands). The names of these projects are *Tick-et* with CICO policy implemented with contact-less cards, *Integrated Public Transport Ticketing* also implementing CICO with dual-interfaced card and *Tripperpass* that uses EPT policy [Ove].

Another project that started around 1995 was *ICARE* [Ré98]. It concerns Lisbon (Portugal), Constance (Germany), Venice (Italy) and Paris (France). This project evolved, with the entrance of Brussels into the consortium, creating a telematics platform, which defines a card-terminal ticketing standard called *Calypso* [Cal]. The protocol used in *ICARE* was a proprietary protocol developed by Innovatron and further on implemented by ASK [ASK,] in France. ASK has also implemented the *Calypso* protocol used in French projects such as *MODEUS* in Paris, which uses a dual-interfaced smart card provided by Schlumberger [Schl] for its CICO policy, and *SunCarte* in Nice with EPT policy. Later on, *Calypso*'s work was divided into two areas. One of them constituted the European project *TRIANGLE* whose aim was to develop a solution to inter-operate between Paris, London and Brussels while the other area made up a working group named COSMIC looking after an intercommunication standard between contact-less devices and the central command systems.

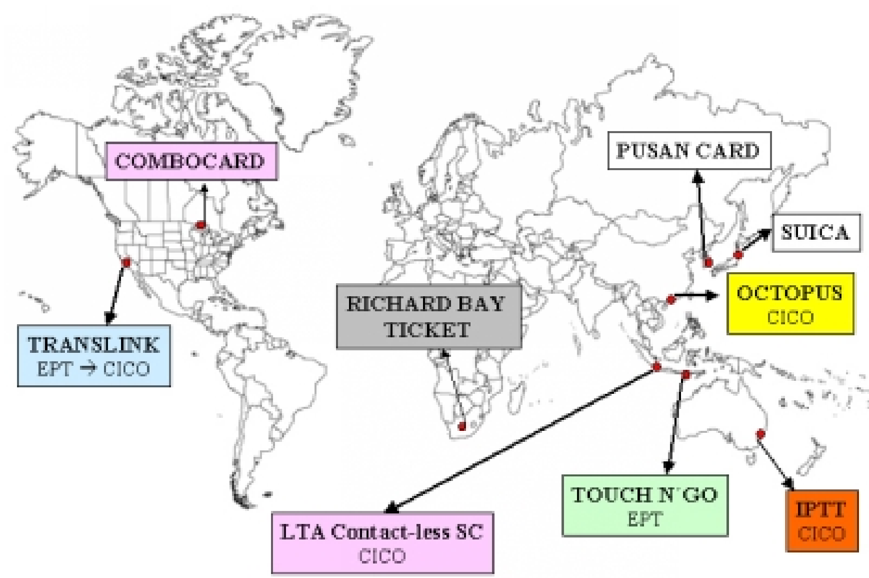

Figure 8: Some E-Ticketing projects around the world

Together with ERG group and Motorola, Cubic Transportation System, which is one of the biggest solution suppliers for electronic ticketing and automatic fare collection, contributed to the projects of Singapore and San Francisco which have already been mentioned. Some other projects on which Cubic is working are *Touch 'N Go* in Kuala Lumpur (Malaysia) which is operative using personalized smart cards provided by Gemplus [CaHu02], with EPT policy, *SGB-Ticket-Uhr* in Freiburg (Germany) operative since year 2000 with EPT policy, *get-in* [Rheia] in Hanau (Germany) just starting with CICO policy, *PRESTIGE* in London (Great Britain) in its introduction phase working with EPT policy, *SmartTripCard* in Washington DC (USA) operative since 1999 and *CTA's Smart Card Customer Pilot Program* in Chicago (USA) planned to be operative this year, both of them using EPT policy. The cubic system is using the smart card *Go-Card* provided by Schlumberger that supports electronic ticketing based on EPT policy as well as time and distance based fare structures and other third party applications [Ove].

The project developed in Switzerland is a new concept in electronic ticketing based systems. Its name is *EasyRide* [GyDe01] and it is based on *Be-In/Be-Out* or *Walk-in/Walk-out* policies using a chip-card designed specially for the project. It started in February 2001 and it is planed to be operative in 2008. The *EasyRide* working group cooperates with the Swatch Consortium [Swat] and its infrastructures have been developed in cooperation with Siemens Transportation Systems and Ascom, a system integrator company that also works in projects like *Carte á Puce* in Hull (Canada) based on EPT policy that allows either personalized or anonymous cards. Ascom cooperates with ASK in the projects *MODEUS* and *SunCarte* [Ove].

VVO (Verkehrsverbund Oberelbe), Germany, initiated a project based on the Easy-Access System from Siemens Transit Telematics AG [Siem] (developed for the first phase of *EasyRide* project), for Dresden. The pilot program is planned to start in 2003 with CICO policy. This project is called *intermobilPass* ([Proj99]) .

intermobilPass and the project *Elektronisches Ticket Bremen*, which was promoted by Verkehrsverbund Bremen/Niedersachsen GmbH (VBN) working with INIT GmbH and VDV, use an e-purse card to perform the payment for public transportation. This e-purse cards used in Germany operate with the payment environment Geldkarte [VÖ].

Phillips Semiconductors [Phil] has developed a contact-less platform that includes readers and cards (contact-less and dual-interfaced) called *MIFARE*. This technology is used in the project *WAYFlow* [Rheib] which creates an integrated public transport system for the Rhein-Main region in Germany. This project is divided into three programs. *MOBICHIP*, which aims to develop a secure and easy-to-use smart card based transport system with the use of a dual-faced smart card. *MOBIMANAGEMENT* is focused on creating the structures for managing the system, and *INFOPOOL* is working to build an information platform based on a multi-agent system.

Q-Free [Q-Fr], a supplier of intelligent transport systems, has selected Schlumberger multi-application dual-interfaced Easy-flex City smart card based on Phillips' MIFARE PRO chip, for the new integrated transport ticketing system in Trondheim (Norway) called *t:kort*. Easy-flex City card provides not only secure infrastructure similar to the one chosen by most of the financial authorities, but also supports different payments methods to different applications.

There are also other existing projects using EPT policy like *DingCard* in Ulm, *LangeoogCard* in Langeoog using *MIFARE* platform, *E-Card* operative since 1996 in Marburg with a contact-less interface, *BNV-Card* [Ove] in Biberach and *Ab und Zu Karte* [OVA 01] operative since 2001 in Aalen all of them in Germany. *MATISSE 2000* in Rimini and *La Carta di Venezia* in Venice, both in Italy. *GoRider* in Auckland City (Newsealand), *Accueil 54* in Meurthe et Moselle (France), *SIROCCO* [PeHe02] in Barcelona (Spain), *Tampere TravelCard* in Tampere (Finland), *Rejsekort* in Denmark, *Uppsalakortet* operative since 1994 in Uppsala (Sweden), *Pusan Card* operative since 1998 in Pusan (Republic of Korea), *Transportation card* operative since 1996 also in Korea, *Suica* in JR East (Japan), *ComboCard* operative since 1995 in Burlington/Ajax (Canada) and a ticketing system in Richards Bay (South Africa) [Ove].

Some of the existing projects led to consortiums aiming at developing common solutions. The first of these associations was created as early as on March 3, 1995 in Konstanz under the name **CLUB** (Contact-Less Users Board) [CLU]. The partners were then Venice, Lisbon, Paris and the Bodensee Region. It was dedicated to contact-less technology with the following motto "*Share experience and progress together*". Nowadays more countries are members of CLUB: Belgium, Denmark, France, Germany, Great Britain, Greece, Italy, Japan, Netherlands, Portugal, Spain and Switzerland.

CLUB also works in association with another research group for electronic ticketing named *Kontiki* [Arbe] from Germany which is constituted by projects such as *EasyRide*, *PRESTIGE*, *WAYFlow*, *intermobilPass*, *TRIANGLE* and *Octopus* and cooperate with international standardization agencies such as International Standardization Organization, (ISO), European Committee for Standardization (CEN) and entities like Union Internationale des Transports Publics (UITP) or Intelligent Transport Smart card Organization (ITSO).

References

[Arbe] Arbeitskreis kontaktlose Chipkartensysteme für Electronic Ticketing e.V., Germany. *kontiki*. Available electronically http://www.kontiki.net.

[ASK,] ASK, France. Available electronically http://www.ask.fr.

[Banc] Banc Sabadell, Spain. Available electronically http://www.bancsabadell.com.

[CaHu02] Cataño, Néstor and Huisman, Marieke. *Formal Specification and Static Checking of Gemplus' Electronic Purse Using ESC/Java*. In *Lecture Notes in Computer Science*, volume 2391, pages 272–289. Springer Verlag, 2002. Information also available electronically http://www.gemplus.com http://www.gemplus.com/products/gemwg10.

[Cal] *Calypso Standard for card terminal ticketing*. Available electronically http://www.calypso.tm.fr.

[CLU] *ContactLess Users Board CLUB*. Available electronically http://www.contactless-club.com.

[Cubi] Cubic Coorporation. Available electronically http://www.cubic.com.

[ERG] ERG Group. Available electronically http://www.erggroup.com.

[Garc02] Garcia Valdecasas Vilanova, M.Eugenia. *Anonymous and Untraceable Electronic Ticketing with Smart Card for Public Transport*. Master's thesis, Fakultät für Informatik, Universität Karlsruhe (TH), Germany, 2002.

[GyDe01] Gyger, Thomas and Desjeux, Olivier. *EasyRide: Active Transponders for a Fare Collection System*. *IEEE Micro*, 21(6):36–42, November/December 2001. Information also available electronically http://www.easyride.ch http://www.emmarin.ch/wevfile/product/rlid/ERE010423.pdf.

[Int] International Organization for Standardization. *Specifications for Smart cards ISO 7816*. Available electronically
`http://www.iso.ch/iso/en/ISOOnline.openerpage`.

[Jung] Junghans Uhren GmbH, Germany. Available electronically
`http://www.junghans.de/wdeutsch/futurewatch/index.shtml`.

[Noki] Nokia. Available electronically
`http://www.nokia.com`.

[Octo94] Octopus Cards Ltd. *The Octopus Project*, 1994. Available electronically
`http://www.octopuscards.com/e_index.html`
`http://lnweb18.worldbank.org/External/lac/lac.nsf/Sectors/Transport/`
`http://www.aesprodata.com.au/transit/projects/index.htm`
`http://www.kcrc.com/eng/service/lrts_octopus.html`.

[OVA 01] OVA – Omnibus Verkehr Aalen, Germany. *Ab und Zu Karte*, 2001. Available electronically
`http://www.ova.de/news/20011201a.html`.

[Ove] An overview over ticketing projects can be found under:
`http://www.tick-et-portal.de/`.

[Paya99] Payan, Jean-Louis. *SIROCCO – Technical Specification of GemCombiWG10 Combicard OS*, SIROCCO EP 26996 edition, February 1999.

[PeHe99] Perez, Andreu and Herrador, Francesco. *SIROCCO – Flows of Information and Format of Files*, SIROCCO EP 26996 edition, March 1999.

[PeHe02] Perez, Andreu and Herrador, Francesco. *SIROCCO Project – Description of the system components and their interconnections*, Deliverable D6. WP: D6. edition, March 2002. Available electronically
`http://www.siroccoproject.com`.

[Phil] Philips Semiconductors. Available electronically
`http://www.semiconductors.philips.com`.

[Proj99] Projektbüro intermobil. *intermobil Region Dresden*, 1999. Available electronically
http://www.intermobil-dresden.de.

[Q-Fr] Q-Free ASA, Norway. Available electronically
http://www.q-free.com.

[Ré98] Régie Autonome des Transport Parisiens, France. *ICARE*, 1998. Philippe Vappereau, Project Coordinator. Available electronically
http://www.cordis.lu/telematics/tap_transport/research/projects/icare.html.

[Rheia] Rhein-Main-Verkehrsverbund, Germany. *Get-in Project*. Available electronically
http://www.rmv-get-in.de.

[Rheib] Rhein-Main-Verkehrsverbund, Germany. *WAYFlow Project*. Available electronically
http://www.wayflow.de.

[Schl] Schlumberger Ltd. Available electronically
http://www.slb.com.

[Siem] Siemens Transit Telematic Systems AG, Switzerland. Available electronically
http://www.hpw.ch.

[Sony] Sony Corporation, Japan. *Sony Felica card*. Available electronically
http://www.sony.co.jp/en/Products/felica/contents02.html.

[Swat] Swatch Group. Available electronically
http://www.swatchgroup.com/home.php.

[Verk99] Verkehrsverbund Rhein-Sieg, Germany. *i.Ti. - The Intelligent Ticket*, 1999. Available electronically
http://www.tick-et-portal.de/dland/bonnkoeln.htm.

[VÖ] VÖB-ZVD, Bank für Zahlungsverkehrsdienstleistungen GmbH, Germany. *Zahlungssystem Geldkarte*. Available electronically
http://www.voeb-zvd.de/geldkarte.htm.