An example of a view on interoperable tolling architectures

NOTE

This is a discussion paper.

As such it contains issues which may be contentious. In order to facilitate the discussion on this view, contentious issues are not ignored but presented with a provisional position.

Jan Vis

January 16th, 2007

Foreword

The architectures presented in this paper are based on the organisational model as defined in the European CESARE III project and as also presented in 'An example of a view on interoperability in tolling and on achieving the aims of directive 2004/52'. [View on interoperability]

The document aims to contribute to our work on the architecture in both the Stockholm Group and ISO TC204/WG5 (= CEN TC278/WG1).

This paper reflects a current view on the subject and may be updated when needed. It is a technical paper in the sense that less concerned with policy, desirability or what should be accomplished but more with possibilities and what can be accomplished. Also, this paper does not aim to include all views of all stakeholders (the common multiple) but at a common denominator.

Even though the subject may be sometimes abstract, the view should be readable for the layman with a common knowledge of tolling.

The Stockholm Group and ISO TC204/WG5 (= CEN TC278/WG1) were invited to comment on earlier versions.

Copyrights

Disclaimer

This paper contains the personal view of the author. It does not present or imply any official position of his employer, the Dutch Ministry of Transport, Public Works and Water Management.

Terminology

The terms 'toll charger' and 'toll service provider' as used in this paper correspond as follows to terms used in Directive 2005/52, proposed in the Cesare III project and by CEN TC278/WG1.

This paper	Directive 2004/52	Cesare III main actors	CEN TC278 / WG1
Toll charger	Operator	Toll charger	Toll charger
Toll service provider	Issuer	EETS provider	Toll service provider

Contents

1. Introduction

1.1 The goal of this paper

This paper provides examples of architectures suited for both interoperability[1] in tolling and ways to achieve the aims of EU Directive 2004/52.

It does so by making recommendations based on analysing various implementations of what is called the 'basic architecture scheme'.

It aims at a situation in which toll systems can evolve and in which new tariff schemes can be introduced as required by the subsidiarity principle.

1.2 Scope

The architectures presented in this paper are based on the organisational model as defined in the European CESARE III project and as also presented in 'An example of a view on interoperability in tolling and on achieving the aims of directive 2004/52' [View on interoperability].

Enforcement and the distribution of toll scheme data are included as well.

Payment, however, is not included. Interoperability in tolling is based on post-payment from central accounts[2]. As payments from central accounts can be accomplished by regular bank transfers this does not need any further attention in this paper.

1.3 A minimalist top-down approach

The approach is a minimalist top-down one. It is based on equipment configurations operated under the responsibility of the main actors, either at a central location, onboard of a vehicle, or along the roadside.

The level of detail of the description of the architecture is governed by the following rule:

- No more detail than required for the first basic decisions,
  i.e. to determine which equipment configuration should deliver which services.
- Equipment of a subcontractor is assumed to operate on behalf of his principal and, therefore, not included in this paper.

[1] Where interoperability is defined as the ability to operate in conjunction (see the SOED)

[2] See [View on interoperability]

2. The basic architecture

2.1 Introduction

This chapter introduces the basic concepts and criteria for the overall architecture and provides an introduction on the description of architectural variants in the next chapter.

In section 2.2 the use of architectures is introduced in abstract terms. Then section 2.3 introduces the basic (intermediate) deliverables in a tolling process and the supporting data needed to produce these deliverables.

Sections 2.4, 2.5, and 2.6 provide the security, adaptability and performance criteria for the evaluation of the architecture variants in the next chapter.

The last section 2.6 provides the basic structure for the architectures described the next chapter.

2.2 The use of architectures

2.2.1 Architecture, a definition

In this paper architecture is defined as:

> *The organisational structure of a system or a software item, identifying its components, their interfaces, and a concept of execution among them. [IEEEJ016]*

More in particular, the components and interfaces for the overall tolling system are identified and the concept of execution among them is described in terms of the services delivered by these components over these interfaces.

The components in the overall tolling architecture are the equipment configurations[3] used by the various actors at a certain location.

Main criteria for describing this structure are:

1. Responsibility for the equipment (including software),
   As in Cesare III the following persons or legal entities are distinguished:
   a. the toll charger
   b. the toll service provider or, for the EETS, the EETS provider
   c. the customer (of the toll service provider)
2. Location of the equipment:
   d. Onboard equipment and/or roadside equipment
   e. Central equipment (i.e. equipment not bound to a vehicle or the roadside)
3. Basic processes required getting the toll to be paid (see below).
4. Security,
   f. As the system deals with money, it should be trusted by all the co-operating actors, this includes measures for enforceability.
   g. Privacy, the architecture should adhere to international and national privacy regulations.

In describing architectures, this paper focuses on:

- Interfaces between equipment configurations and
- Services to be provided or used by such equipment configurations

[3] Often the term 'equipment' is used as a short hand for 'equipment configuration'

2.2.2 Focus on interfaces

This paper focuses on the interfaces, the common boundary, between equipment configurations supplied / used / controlled etc. by different parties.

The internal structure of the equipment configurations is outside the scope of this paper and left to discretion of an implementer[4,5].

Two types of interfaces are distinguished:

- Interoperability interfaces
  i.e. interfaces between equipment configurations operating under the responsibility of toll service providers and equipment configurations operating under the responsibility of toll chargers to support interoperability in tolling
- Internal interfaces
  i.e. interfaces between equipment configurations operating under the responsibility of one actor, e.g. a toll service provider or a toll charger.

2.2.3 Focus on services / deliverables

Using OSI terms, this paper focuses on the services[6] delivered by one component (equipment configuration) and used by another component (equipment configuration).

The applications or functions[7], i.e. the internal software or modules needed to deliver these services, are outside the scope of this paper.

In simple words, this paper focuses on how the architectural components should behave, not a what they should do to exhibit that behaviour.

2.3 Basic deliverables

The figure below provides an overview of elementary processes in terms of the data they deliver[8]. The processes are defined in terms of their output as described below.

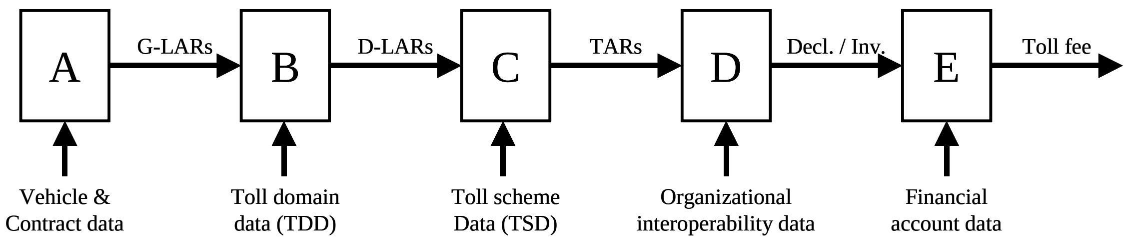


Figure 2-1 Elementary process defined in terms of the data they deliver

The horizontal arrows represent the data delivered by the processes A – E, and the vertical ones the data needed to perform a process.

---

4 As a consequence, any distinction between hardware, software, and applications is outside the scope of this paper.

5 The integration of OBE for tolling into vehicles and with other OBE is dealt with in a forthcoming paper. See [View on OBE architectures]

6 **Service:** A capability of a system or component, which is provided to other systems and/or components at the boundary between the service providing system or component and the system or component using the service. (based on ISO 7498-1)

7 **Function:** part of the activity of active elements within a system embodying a set of capabilities defined for that system (based on ISO 7498-1).

8 Derived from [Mister2004]with the emphasis on the interfaces.

The types of data that can be delivered are:

1. Generic Location Account Records (G-LARs)
   records with location, time, and vehicle information that can be used for any toll domain supported by the OBE contract. A location account record may e.g. contain a contract identifier, the vehicle's registration number[9], the time, the current vehicle location, and the required vehicle parameters[10].
2. Toll Domain Specific Location Account Records (D-LARs)
   G-LARs for a particular toll domain and with the vehicle parameters possibly reduced to only those relevant for this particular toll domain.
3. Toll Account Records (TARs)
   Records describing a valid claim for fee for an elementary tolled object, e.g. a bridge, a stretch of road (or time spent) in a tolled network. A TAR is assumed to correspond to an item on an itemized declaration or invoice.
4. Invoices or declarations (to be paid without awaiting an invoice)
   Statements of the toll fee sum due, based on the list of TARs for some period. This statement may or may not be itemized, i.e. may or may not contain the TARs on which it is based.
   Declarations are assumed to be drawn up by or on behalf of the toll service provider, invoices by or on behalf of the toll charger.
5. Toll fee
   The fee paid on the basis of a declaration or an invoice.

The data needed to support these elementary processes consist of:

1. vehicle and contract data,
   This data encompasses all data needed to create the G-LARs
2. Toll domain data (TDD)
   The only toll domain data required for selection of the relevant toll domain (and its toll charger) are the toll domain boundaries[11]. Besides, a list of vehicle parameters relevant for that toll domain might be useful to reduce the size of the individual D-LARs.
3. Toll scheme data (TSD)
   The toll scheme data needed to calculate TARs for given D-LARs is the tariff data and, if the tariff is location (e.g. road type) dependent, the tolled objects and the tariff data per set of tolled objects.
4. Organisational interoperability data
   This data includes e.g. arrangements about the frequency of declarations or invoices and any additional service to be added or substracted.
5. Financial account data
   The date includes e.g. information about the banking accounts used for the transfer of monies. (this data may as well be included in the organisational interoperability data)

2.4 Security

Security is of major importance for two reasons:

1. Trust,
   because toll systems are dealing with money.

---

[9] See under enforceability, unobtrusive surveillance.

[10] The details are outside scope of this paper.

[11] Note that this selection is only relevant for the GNSS based systems. So, currently, the only relevant borders are borders from Switzerland and Germany. For Germany one might think of defining the border of the toll domain as the 'borders' of the German motorways, but in the current discussion on light-fat OBEs most authors regard 'map-matching' a part of the TAR calculation.

This requires 'valid toll declarations' between the equipment of toll service providers and the equipment of toll chargers[12] and enforcement measures to compel the adherence to a toll regime.

2. Privacy,
requiring a confidential treatment of privacy sensitive (route) information.

As no one can be expected to behave in an insecure way, equipment (and especially OBE suitable for use in multiple toll domains) must be trusted by the toll chargers and must adhere also to enforcement requirements.

It should be noted that enforceability and privacy are to some extent conflicting. The support of these values should be balanced.

2.4.1 Valid toll declarations

The basic idea is that a 'valid toll declaration'[13] between OBE and a toll system provides a toll charger with a valid and undisputable claim for the fee on a toll service provider and/or its customer.

Note that a 'valid toll declaration' only implies that the responsibility for the content is clear, not that the data is correct. Valid data may be incorrect[14].

The moment a toll system regards the communication with the OBE as valid, can be seen as the moment that a toll agreement is concluded or the moment that the one(s) liable for toll fulfilled their toll declaration responsibilities.

The concept of a 'valid toll declaration' is used in this paper as the 'linking pin' between:
1. the equipment interoperability and the organisational interoperability,
2. the toll service provider and the toll charger, and
3. the charging and enforcement measures and procedures.

2.4.2 Enforceability

Enforcement measures are an essential part of tolling services. In this paper the focus is on enforceability, on the possibilities to detect violations of the toll regime. Procedures for tracking down the one(s) liable, for settlement, for prosecution, and for the execution of verdicts are outside the scope of this paper[15].

With respect to the detection of violations the following types of measures can be distinguished:

1. Unobtrusive surveillance[16],
e.g. with video techniques, in which case the toll statements from the vehicle can be checked afterwards on their consistence with presence of the vehicle as observed by a video camera[17].

2. OBE interrogating with on the spot checks[18]
by interrogating the OBE and on the spot checking the validity of the response.

3. OBE interrogating with checks afterwards
in which case the response of the OBE is checked afterwards on its consistency with the valid toll statements received from the OBE.

---

[12] See [View on interoperability]

[13] The actual authentication mechanism is, however, outside the scope of this paper. The data may e.g. be signed by or on behalf of the toll service provider.

[14] A properly signed message may still contain incorrect data. E.g., the number of axles or the presence of a trailer may be incorrect. Nevertheless, it provides the toll charger with a wrong but valid claim.

[15] See [View on interoperability] for a short overview of these issues.

[16] Unobtrusive is used here as not noticeable for the OBE, therefore OBE interrogation is not unobtrusive.

[17] Note that this is only possible if the D-LARs as send to the toll charger also contains the vehicle's registration number.

[18] Note that this includes both, regular (DSRC) /charging transactions as well as dedicated enforcement transactions.

The last variant, interrogating the OBE with checks afterwards, is especially important in cases where it is not sure that the sum as calculated in a declaration or invoice is based on the same data as received when the OBE was interrogated. In other words, when it is possible that the OBE might 'lie' when it is interrogated[19]. On the other hand one should notice that, as the OBE is aware of interrogation, it might only lie when it has not been interrogated.

The dilemma presented in the previous paragraph can be avoided by securely monitoring the toll payment process in the OBE[20].

2.4.3 Confidentiality

For confidentially two types of measures are considered:

1. making no more data available then necessary
2. guarantees provided by the actors (which may be laid down in contracts)

Provisions to ensure the confidentiality of the communication between the equipment configurations are outside the scope of this paper[21].

2.5 Performance issues

With respect to performance issues it is assumed that:

1. (international) communication costs are significant
2. onboard processing and storage are relatively cheap
3. the time and costs to develop and maintain mature equipment including software might be significant.

2.6 Adaptability

2.6.1 Introduction

Panta rei, everything changes (Heraclitus, 536-470 BC). This holds for the EETS as well and is of particular importance for the services delivered by and communication with the OBE. Changes may have various causes. One may think of technological developments but also of the right of EU member states to introduce new toll regimes[22]. As a consequence, the capability to change has to build in into the system right from the start.

Even in case of changes in one toll domain, it is impossible to change both all the operational OBE and the toll system at the very same moment. As a consequence the EETS should be able to deal with some legacy. There are three different options to consider:

1. require the OBE to adapt first
   and be interoperable with both the old and the new toll system(s)
2. require toll systems adapt first
   and be interoperable with both old and new OBE
3. provide for a provisional fallback solution

[19] So simply asking whether or not the OBE 'feels well' of has successfully completed its self-diagnostic tests is of little value. Unless, perhaps, the response can be used to proof 'forgery' in case it shows to be incorrect.

[20] See the forthcoming [View on OBE architectures] for details.

[21] Confidentiality of the communications is a technical issue that can easily be resolved in any of the described architecture variants.

[22] Based on the subsidiarity principle and also explicitly formulated in article 3(2) the EU directive 2004/52

In all cases the communication between the OBE and the toll system has to able to distinguish and to cope with different protocol versions[23].

2.6.2 Require the OBE to adapt first

In this case there is a transition period in which the OBE which are already adapted to the new toll system(s) still have to be interoperable with old system(s) as well.

The feasibility of this option depends on the means to adapt the OBE[24]. Cases to be distinguished are:

1. Remote software updates by the toll service provider (if possible)
2. OBE updates at service stations
3. Replacement of OBE

Due to the number of OBE already installed in vehicles and the organisational burden involved updating this OBE, the last two cases may require quite a long transition period (even after certified solutions have became available) and should be announced well in advance. See also the section on mitigating the consequences of the subsidiarity principle in [View on interoperability].

It should be noted that for the simpler OBE (i.e. OBE delivering LARs instead of TARs) there are less reasons for adaptations.

2.6.3 Require toll system(s) to adapt first

In this case there is a transition period in which renewed toll systems still have to be interoperable with old OBE as well.

Especially when the toll charger has required the adaptation, this may be the most reasonable solution with respect to the allocation of costs and effort.

This option has no consequences for architecture variants described in the next chapter.

2.6.4 Provide for a provisional fallback solution

As a third option one might allow for a ‘degraded’ fall back mode of communication between the OBE and the toll system(s).

When a toll system has been updated, old OBE capable of exchanging e.g. TARs with the old toll system may then be allowed to exchange LARs with the adapted system.

Incentives for the toll service provider to update the OBE may be built in by applying different fees for more or less capable OBE[25].

---

[23] Communication protocols should be designed to be extensible and the communicating equipment should be capable to deal with extensions (i.e. either to use then or to ignore them, whatever is applicable). However, it is unclear to what extent, if possible at all, the current communication protocols and the operational toll equipment are capable to do so.

[24] See the forthcoming [View on OBE architectures] for details.

[25] Like some toll regimes already apply a different fee of equipped and non-equipped uses (as e.g. in Toronto).

2.7 The basic structure

2.7.1 Equipment configurations as the structural component

The figure below shows the basic structure, irrespective of the distribution of functions over the equipment configurations:

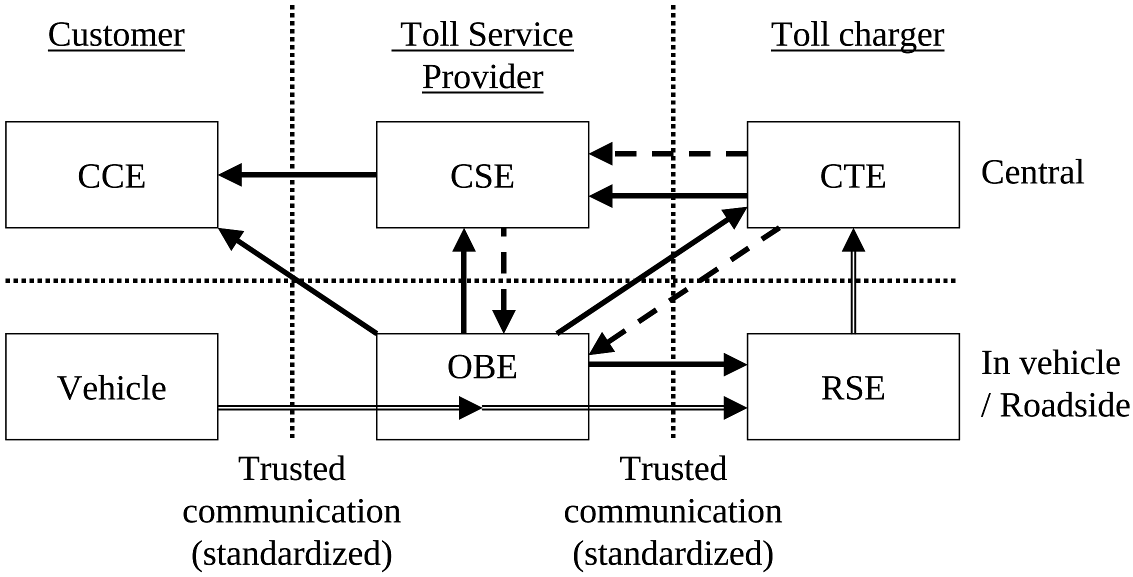


Figure 2-2 The basic structure (irrespective of the distribution of functions)

The top row shows the central equipment configurations operating under the responsibility (on behalf) of the customer, the toll service provider and the toll charger: the central customer equipment (CCE)[26], the central toll service provider equipment (CSE) and the central toll charger equipment (CTE).

The bottom row shows the vehicle, the OBE operating under the responsibility of the toll service provider, and the roadside equipment (RSE) including mobile equipment as appropriate. The RSE operates under the responsibility of the toll charger.

The solid lines represent the possible interfaces for the exchanges of data between the various equipment configurations. Which interfaces are actually implemented depends on the chosen architecture. (see the next chapter).

The dashed arrows represent the support of less frequent (e.g. toll scheme) data transfers.

The double shaft arrows represent possible data exchanges used for enforcement. Roadside equipment may both observe the vehicle and the OBE.

2.7.2 The need for standardized interfaces

2.7.2.1 Interfaces between customers, toll service providers and toll chargers

Interfaces between the equipment of customers, toll service providers and toll chargers are represented in the figure above by horizontal and diagonal arrows.

[26] The CCE is often neglected, but relevant for the processing of electronic invoices and/or obtaining data logs from the OBE. The fact that the OBE operates under the responsibility of the toll service provider does not imply that the customer has no right to see what it is doing.

In order to guarantee a smooth operation of the whole system, the interfaces between the toll service provider equipment and the toll charger equipment should be completely standardized[27].

The same holds to a lesser extent for the interfaces between the equipment under control of the toll service provider and the equipment of his customers. However, also standardization of this interface might be useful when hauliers use a variety of OBE and want to integrate the payment of toll into their logistic systems.

As shown below about the same data is exchanged on all these interfaces, when implemented. This makes the standardization effort less extensive then it might look like at a first glance.

2.7.2.2 Internal interfaces

These interfaces are interfaces between equipment configurations under responsibility of the same actor. Although these interface do not need to be standardized for interoperability reasons, standardization may be important for the procurement of equipment by toll service providers and/or toll chargers from different vendors / manufactures.

Standardization of the communication between roadside equipment and central toll charger equipment will allow toll chargers to procure roadside equipment independent of the operation of their central equipment. This may be especially relevant when the roadside equipment is outsourced.

For the same reason the communication between the OBE and the central toll service provider equipment could be standardized.

[27] In Europe an EETS provider may have to deal with about 100 more or less independent toll chargers.

3. Overall architecture variants

3.1 Overview

The figure below gives an overview of the architectures considered in the paper. For each architecture A-G it is indicated which equipment produces which output. The various configurations are further elaborated in the next sections.

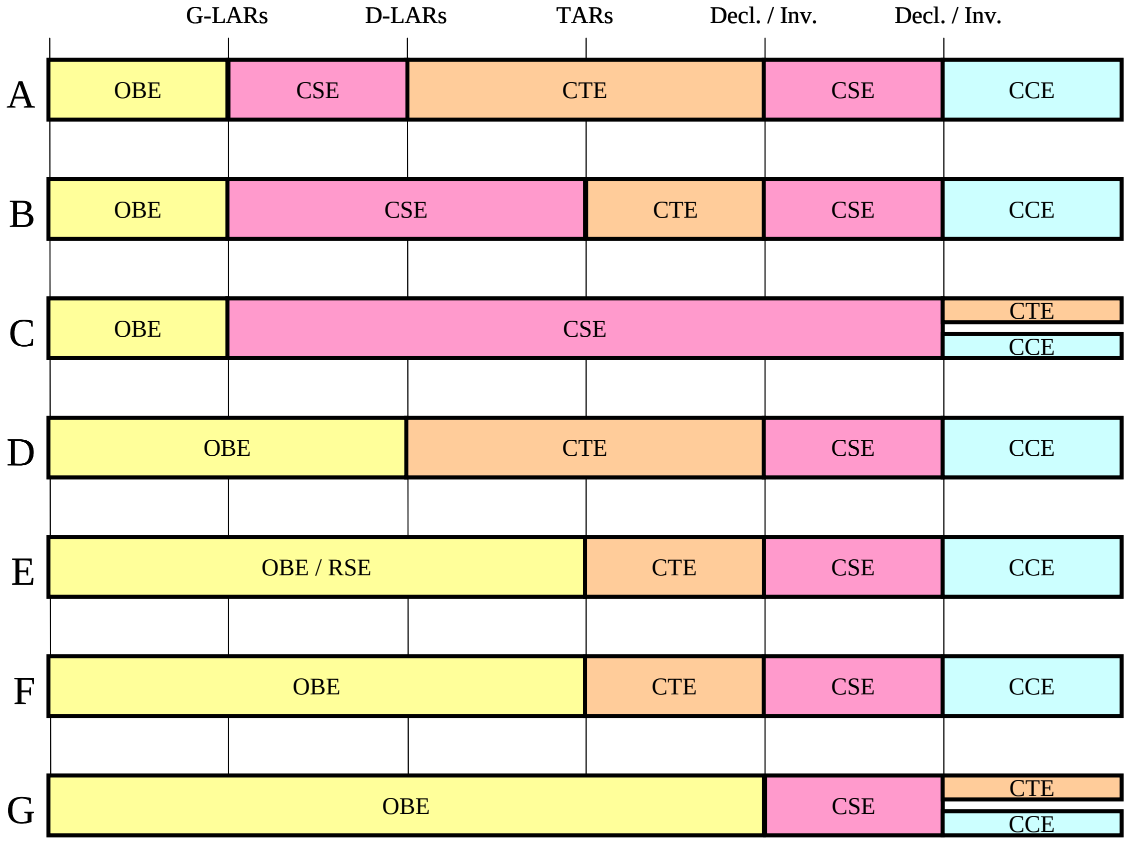


Figure 3-1 Overall architecture variants

In the variants A, B, D, E, and F invoices are sent from the CTE via the CSE to the CCE. In variants C and G declarations are sent by the CSE to both the CTE and the CCE.

As said before, the payment of a declaration or invoice by the central customer equipment are outside the scope of this paper.

It should be noted that the figure above is not exhaustive and might be extended with other variants.

Also note that combinations may be used as well. E.g., OBE sending TARs to the CTE in one toll domain may send D-LARs to the CTE in another toll domain. (See also 2.6 ‘Adaptability’)

3.2 Variant A: G-LARs to the toll service provider, D-LARs to the toll charger

3.2.1 Process flow

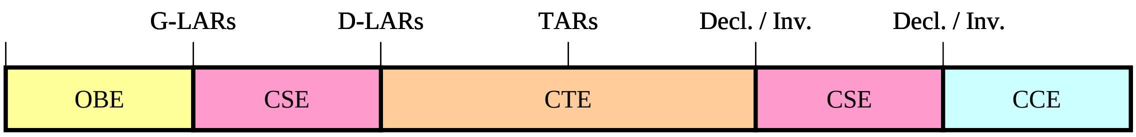


Figure 3-2 Process flow Variant A

3.2.2 Architecture

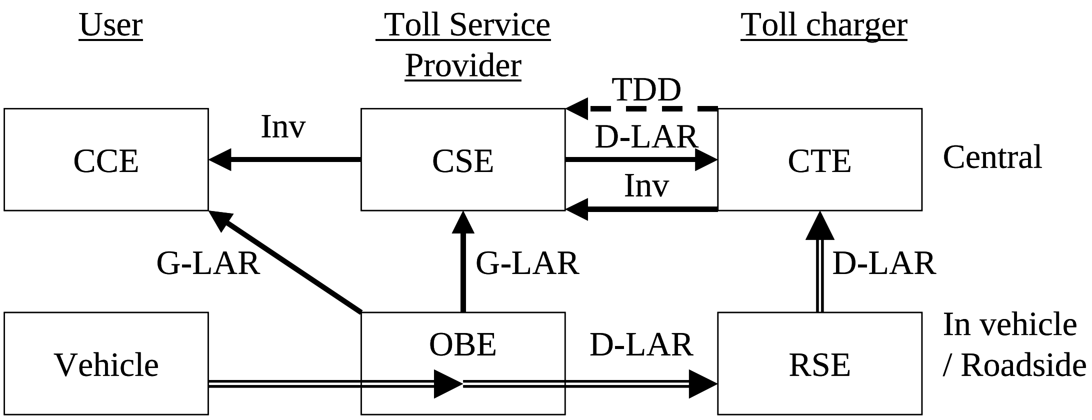


Figure 3-3 Architecture variant A

3.2.3 Description

With this architecture most of the processing is performed under the responsibility of the toll charger. The OBE only produces generic location account records which are all send to the central toll service provider equipment and from there, based on the toll domain data from the toll chargers, passed to the responsible toll chargers.

The toll declaration that provides the toll charger with a valid claim for the fee is in this case the valid transfer of the D-LARs from the toll service provider to the toll charger.

The toll charger then calculates the amount of toll fee to be due and sends, e.g. monthly, an invoice to the toll service provider, which, in turn, presents an invoice to his customer.

The customer may check his invoice with (a copy of) the location account record obtained from the OBE. For this reason he may require an itemized invoice that contains both the original LAR produced by the OBE and the toll account records produced by the toll charger.

The only toll domain data required by the toll service provider for selection the toll charger that needs the LARs are the toll domain boundaries.

3.2.4 Enforceability

Enforcement may be accomplished by unobtrusive surveillance. The toll charger can then check afterwards if the observed presence of the vehicle corresponds with the D-LARs he receives from the toll service provider.

Besides, RSE may interrogate the OBE by requesting copies of the G-LARs. As the toll domain in which the RSE is located is known, these G-LARs are by definition D-LARs.

On the spot checking might be possible for the D-LARs in case one can be sure that the same LARs were sent or are to be sent to the central toll service provider equipment and, subsequently, passed to the central toll charger equipment.

Interrogating the OBE with checks afterwards is feasible when it is trusted that the behaviour of the OBE does not depend on its being checked.

3.2.5 Privacy

As both the toll service provider and the toll charger need the LARs to perform their tasks, both should guarantee that they would not use the data for any other purposes.

3.2.6 Performance

This architecture requires quite some (international) communications. Even when a roaming vehicle is driving completely outside any toll domain, it still has to sent its G-LARs to the central toll service provider equipment.

3.2.7 Adaptability

The production of LARs is less vulnerable for toll regime changes then the production of TARs, invoices or declarations. Therefore, this architecture is less vulnerable for adaptations then the ones with more capable OBE.

3.2.8 Conclusion

This architecture is quite feasible for next few years. Because of the simple OBE it can be implemented in due time and, in case the own OBE of a toll charger also performs some additional processing he only has to port this processing to his own central equipment.

Nevertheless it is expected that this architecture will be replaced gradually by ones that make more use of the OBE capabilities (processing power) and requiring less (international) communication.

3.3 Variant B: G-LARs to the toll service provider, TARs to the toll charger

3.3.1 Process flow

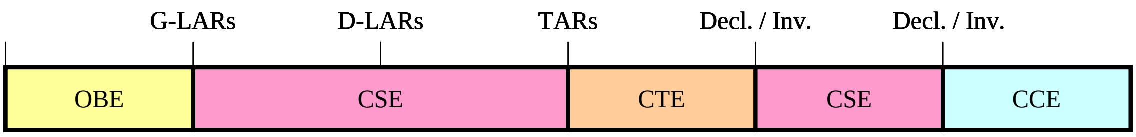


Figure 3-4 Process flow Variant B

3.3.2 Architecture

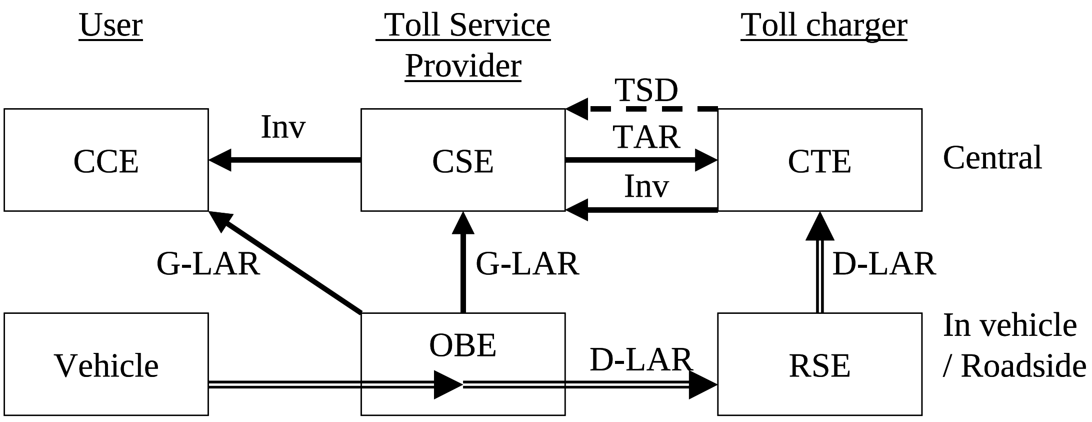


Figure 3-5 Architecture variant B

3.3.3 Description

With this architecture the OBE only produces generic location account records which are all send to and processed by the central toll service provider equipment. The central toll service provider equipment calculates the TARs and passes them to the toll charger.

The toll declaration that provides the toll charger with a valid claim for the fee is in this case the valid transfer of the TARs from the toll service provider to the toll charger.

The toll charger then calculates the total, e.g. monthly, amount of toll fee to be due and sends the invoice to the toll service provider, which, in turn, presents his invoice to his customer.

The customer may check his invoice with (a copy of) the location account records obtained from his OBE. For this reason he may require an itemized invoice that contains both the original LARs produced by the OBE and the toll account records produced by the toll service provider.

In order to be able to calculate TARs a toll service provider needs the full toll domain and tariff data.

In case of a dynamic tariff[28], the toll charger has to distribute the actual tariffs to all toll service providers with customers that may drive in his toll domain.

In case of a location (e.g. road type) dependent fee, care has to be taken that the toll service provider maps the LARs to the right tolled objects (and e.g. not to a service road parallel to a tolled main road).

[28] E.g. a tariff that depends on traffic characteristics and is used for traffic management purposes.

Disputes can be avoided if the toll service provider performs this mapping with software supplied or specified by the toll charger. This, however, would make the toll service provider a kind of subcontractor of the toll charger which is inconsistent with the aim of his role in the process, i.e. in issuing valid toll declarations to a toll charger as defined above [29].

3.3.4 Enforceability

Enforceability is more complex than in the variant A.

Enforcement may be accomplished by unobtrusive surveillance. The toll charger can then check afterwards if the observed presence of the vehicle corresponds with the D-LARs he receives from the issue.

Besides, RSE may interrogate the OBE by requesting copies of the G-LARs. As the toll domain in which the RSE is located is known, these G-LARs are by definition D-LARs.

On the spot checking of the D-LARs is of limited value. Even in case one can be sure that the same LARs were sent or are to be sent to the central toll service provider equipment, one also has to be sure that these LARs are correctly processed by the central toll service provider equipment to calculate the TARs.

Interrogating the OBE with checks afterwards is feasible when it is trusted that the behaviour of the OBE does not depend on its being checked. And in this case too one also has to be sure that these LARs are correctly processed by the central toll service provider equipment to calculate the TARs.

3.3.5 Privacy

From a privacy point of view this architecture is equivalent to the previous one.

As the toll service provider needs the LARs and the toll charger needs the TARs, both should guarantee that they would not use this data for any other purposes.

3.3.6 Performance

The OBE performance is the same as for variant A. This architecture requires quite some (international) communications. Even when a roaming vehicle is driving completely outside any toll domain, it still has to sent its G-LARs to the central toll service provider equipment.

3.3.7 Adaptability

The adaptability is less then for variant A. In case of changes in a toll regime, the toll charger has to update the CSE of all the toll service providers.

3.3.8 Conclusions

This variant has no clear advantage when compared with variant A. Disadvantages are an ambiguous role of the toll service provider and the additional complexity of enforcement and adaptability.

Therefore, this variant is not advisable.

[29] The aim of the valid toll declarations is to make clear when the toll charger obtains a valid claim for the fee on the toll service provider or his customer. A subcontractor of the toll charger, however, is supposed to act on behalf of the toll charger. These are conflicting roles.

3.4 Variant C: G-LARs to the toll service provider, declarations to the toll charger

3.4.1 Process flow

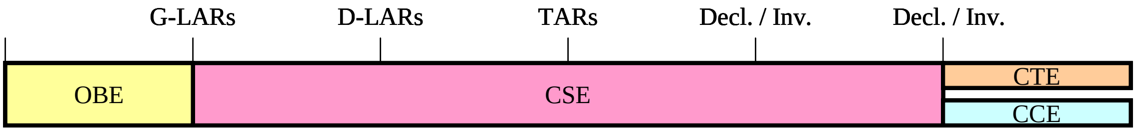


Figure 3-6 Process flow Variant C

3.4.2 Architecture

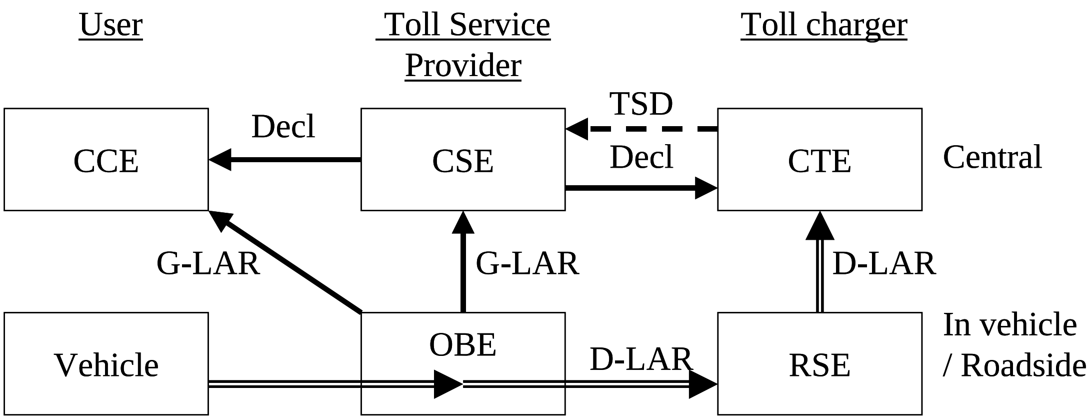


Figure 3-7 Architecture variant C

3.4.3 Description

With this architecture the OBE only produced generic location account records which are all send to and processed by the central toll service provider equipment. The central toll service provider equipment generates the declaration (e.g. monthly) and passes it to the toll charger and his customer.

The toll declaration that provides the toll charger with a valid claim for the fee is in this case the valid transfer of the invoice from the toll service provider to the toll charger.

The customer may check his invoice with (a copy of) the location account records obtained from his OBE. For this reason he may require an itemized invoice that contains both the original LARs produced by the OBE and the toll account records produced by the toll service provider.

In order to be able to calculate TARs a toll service provider needs the full toll domain and tariff data.

In case of a dynamic tariff[30], the toll charger has to distribute the actual tariffs all toll service providers with customers that may drive in his toll domain.

In case of a location (e.g. road type) dependent fee, care has to be taken that the toll service provider maps the LARs to the right tolled objects (and e.g. not to a service road parallel to a tolled main road). Disputes can be avoided if the toll service provider performs this mapping with software supplied or specified by the toll charger. This, however, would make the toll service provider a kind of subcontractor of the toll charger which is inconsistent with the aim of his role in the process, i.e. in issuing valid toll declarations to a toll charger as defined above[31].

[30] E.g. a tariff that depends on traffic characteristics and is used for traffic management purposes.

[31] See also the note on this subject in the description of variant A.

3.4.4 Enforceability

Enforceability is may be even more complex than in the variant B.

Checks afterward are only possible in case

- the central toll service provider equipment sends the central toll charger equipment an itemized declaration, i.e. a declaration with all the TARs and/or D-LARs it is based on, or
- the toll charger may request the toll service provider at random (or in case of a suspicion) that he presents him the TARs and/or D-LARS for inspection. However in that case he should sure that this list of TARs and/or D-LARs is not manipulated afterwards[32].

Enforcement may be accomplished by unobtrusive surveillance. The toll charger can then check afterwards if the observed presence of the vehicle corresponds with the D-LARs he receives from the toll service provider.

Besides, RSE may interrogate the OBE by requesting copies of the G-LARs. As the toll domain in which the RSE is located is known, these G-LARs are by definition D-LARs.

On the spot checking of the D-LARs is of limited value. Even in case one can be sure that the same LARs were sent or are to be sent to the central toll service provider equipment, one also has to be sure that the these LARs are correctly processed by the central toll service provider equipment to calculate the TARs and the declaration.

Interrogating the OBE with checks afterwards is feasible when it is trusted that the behaviour of the OBE does not depend on its being checked. And also in this case one also has to be sure that these LARs are correctly processed by the central toll service provider equipment to calculate the declaration.

3.4.5 Privacy

In case a declaration is sent to the toll charger including TARs and/or LARs this architecture is from a privacy point of view equivalent to the previous one. As the toll service provider needs the LARs and the toll charger receives the TARs and/or LARs both should guarantee that they would not use this data for any other purposes.

In case a declaration is sent to the toll charger without TARs or LARs the privacy is in this architecture better protected then in the previous one. As only the toll service provider needs the LARs, only he should guarantee that he would not use this data for any other purposes.

3.4.6 Performance

The OBE performance is the same as for variant A. This architecture requires quite some (international) communications. Even when a roaming vehicle is driving completely outside any toll domain, it still has to sent its G-LARs to the central toll service provider equipment.

3.4.7 Adaptability

The adaptability is less then for variant A and a little less then for variant B. Changes in a toll regime and in declaration arrangements must be distributed to the CSE of all the toll service providers.

3.4.8 Conclusions

This variant has no clear advantage when compared with variant A. Disadvantages are an ambiguous role of the toll service provider and the additional complexity of enforcement and adaptability.

When compared with variant B, there is more room for a trade off between enforceability and privacy.

Nevertheless, this variant is not advisable.

---

[32] Which can be accomplished quit easily by requiring that the declaration should contain a so-called hash-code over the list of TARs and/or D-LARs.

3.5 Variant D: D-LARs from the OBE to the toll charger

3.5.1 Process flow

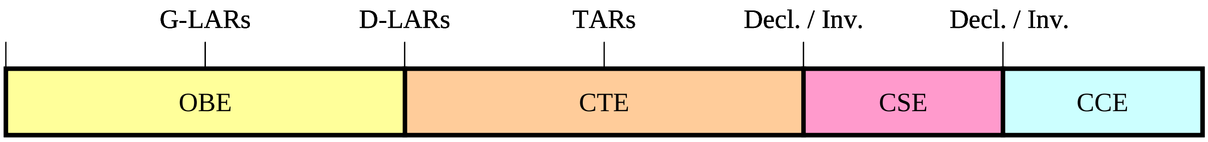


Figure 3-8 Process flow Variant D

3.5.2 Architecture

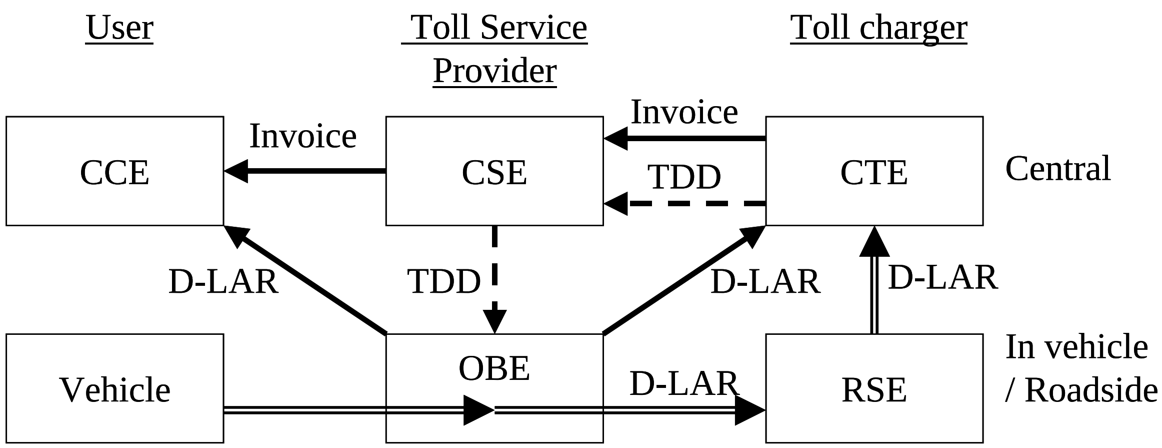


Figure 3-9 Architecture variant D

3.5.3 Description

In this architecture the OBE sends D-LARs directly to to the toll charger. The toll charger then calculates the TARs and draws up the invoice.

The toll declaration that provides the toll charger with a valid claim for the fee is in this case the valid transfer of the D-LARs from the OBE to the toll charger.

The only toll domain data required by the OBE for selection the toll charger that needs the LARs are the toll domain boundaries. This date can be passed by the toll charger to the toll service provider and by the toll service provider to the OBE. As this data does not change to often, this seems to be quite feasible for, at least. the next few years[33].

An alternative (not shown) is an architecture in which the TDD is sent directly from the central toll charger equipment to the OBE. In such an architecture, however, the OBE should first contact the toll charger[34]. This (not shown) alternative is therefore not recommended for the first coming years.

[33] Currently, there are within Europe only to GNSS based systems operational: in Switzerland and in Germany. And, it is not expected that this number will increase much in next five years.

[34] This may be accomplished with roaming provisions as defined in the draft ISO 17575 standard. However, considering the amount of serious comments on the draft in March 2005 an acceptable new version is not to be expected before 2007.

3.5.4 Enforceability

As all LARs are now directly sent form the OBE to the central toll charger, enforceability is much better the in variant A.

All date obtained by enforcement measures can be checked with the D-LARs received without any risk for errors or fraud in the use of the central toll service provider equipment.

3.5.5 Privacy

As in this variant the toll service provider do not need any LARs or TAR privacy is better protected then in variant A.

Nevertheless some customers may require an itemized invoice and in that case the TARs are also passed via the toll service provider. But this can be made dependent on the wish of the individual customer.

3.5.6 Performance

This variant needs, at least for the time being, much less communication capacity then variant A. In this variant there is no need to transmit any LARs if the vehicle is not driving in the toll domain of a GNSS based toll system.

Note that at the expense of receiving some superfluous LARs there is no need for very precise specification of the boundaries of a toll domain. It suffices when the toll domain lies completely within the specified boundary.

3.5.7 Adaptability

The adaptability is the same as for variant A.

3.5.8 Conclusions

When compared with A this variant shows improved enforceability, improved performance, and improved privacy only at the expense of the need for downloading rough toll domain boundaries into the OBE.

Therefore, this architecture is preferred to variant A and should be used for all OBE in which the toll domain boundaries can be downloaded.

3.6 Variant E: DSRC TARs from the OBE to the toll charger

3.6.1 Process flow

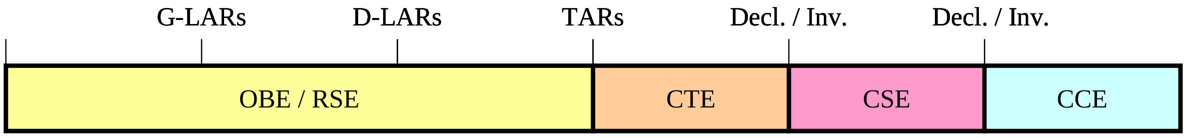


Figure 3-10 Process flow Variant E

3.6.2 Architecture

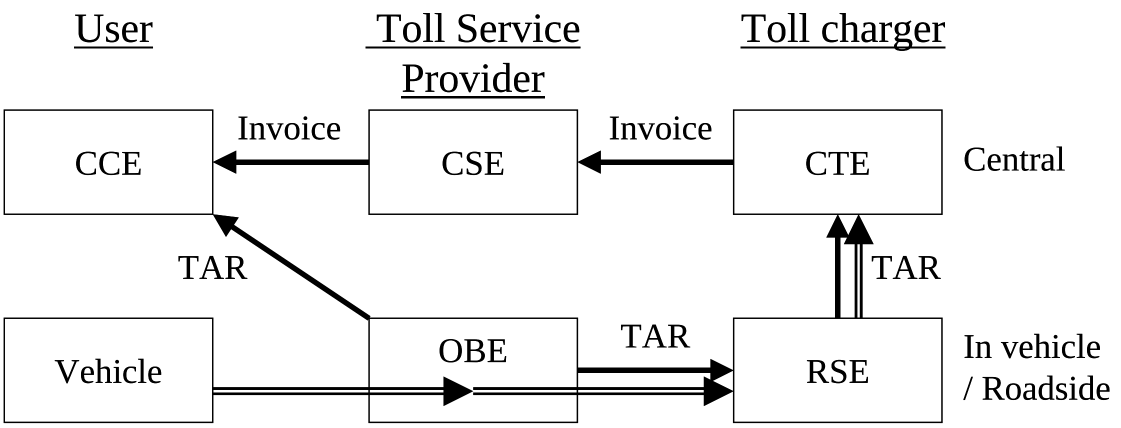


Figure 3-11 Architecture variant E

3.6.3 Description

This is the well known architecture for DRSC systems using the CardMe transactions.

The toll declaration that provides the toll charger with a valid claim for the fee is in this case the valid transfer the result of the CardMe presentation transaction[35] (the TAR in more generic terms) from the OBE to the RSE.

3.6.4 Enforceability

The regular enforcement is in this case an on the spot check. If the OBE has sent a valid and correct message the vehicle may pass. If not the vehicle should be stopped or its registration number should be registered[36].

[35] In CardMe terms, the response of the OBE in the presentation phase. In a closed network this response only proved a valid claim for fee when the vehicle passes the exit gantry. On entrance this response may be interpreted as a statement on behalf the toll service provider that one is willing to pay the fee determined when passing the exit gantry.

[36] See [View on interoperability]for an short overview of the possible procedures for (cross-border) enforcement based on the vehicle's registration number.

3.6.5 Privacy

The protection of the privacy is equivalent to the previous variant D.

3.6.6 Performance

The performance is optimal for DSRC based systems.

3.6.7 Adaptability

As the production of TARs is more vulnerable for toll regime changes then the production of LARs, this architecture is more vulnerable to adaptations then the previous variants[37].

3.6.8 Conclusions

This architecture is well suited for the current interoperable DSRC systems [38].

Nevertheless the protocol for the communication between OBE and RSE may need to be revised if new toll regimes will use new vehicle parameters.

[37] This is also indicated by the intensive debate on new vehicle parameters.

[38] Note that that this paper only focuses on the overall architecture. The extensibility of the CardMe transaction to cope with new vehicle characterises (allowed in the EU because of the subsidiarity principle) and the ability to use the security mechanisms on a EU-wide scale are outside its scope and may need further investigation.

3.7 Variant F: TARs from the OBE to the toll charger

3.7.1 Process flow

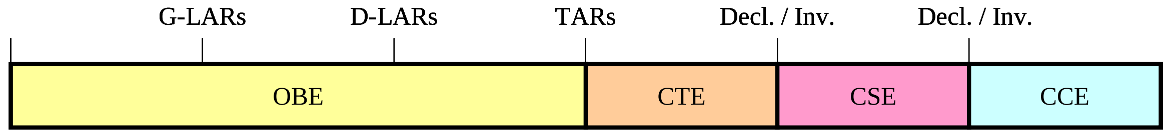


Figure 3-12 Process flow Variant F

3.7.2 Architecture

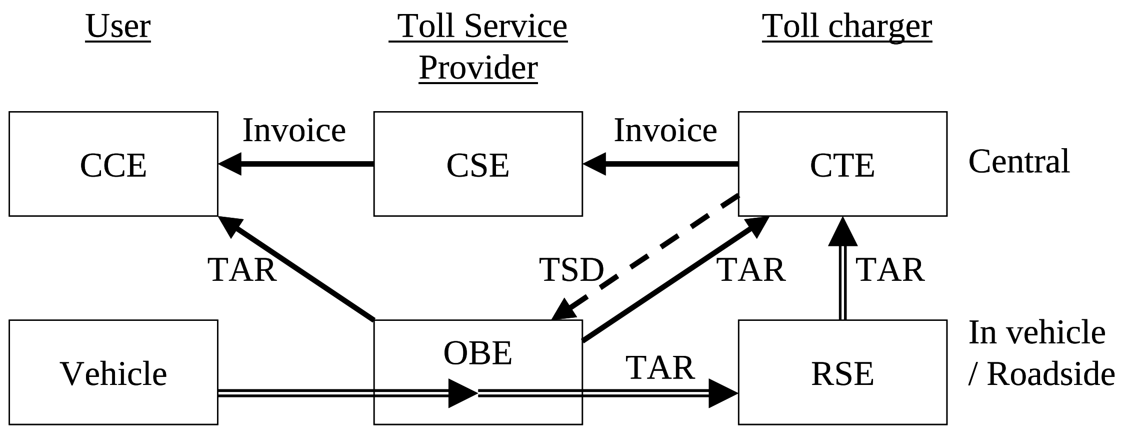


Figure 3-13 Architecture variant F

3.7.3 Description

In this architecture the OBE sends TARs directly to to the toll charger. The toll charger then only has to drawn up the invoice.

The toll declaration that provides the toll charger with a valid claim for the fee is in this case the valid transfer of the TARs from the OBE to the toll charger.

In order to be able to calculate TARs the OBE needs the following toll scheme data (TSD): the full toll domain and the tariff data.

In case of a dynamic tariff[39], the toll charger has to distribute the actual tariffs to all vehicles that are approaching or driving in his toll domain[40].

In case of a location (e.g. road type) dependent fee, care has to be taken that the OBE correctly determines the right tolled objects[41]. Arrangements for the loss of GNSS signals (e.g. in urban canyons) must be considered as well[42].

---

[39] E.g. a tariff that depends on traffic characteristics and is used for traffic management purposes.

[40] How this is accomplished, e.g. via a cellular network or via DSRC bacons , is outside the scope of this paper.

[41] And e.g. do not suppose that the vehicle is on a service road parallel to a tolled main road.

[42] How can a toll service provider convince a toll charger that the equipment was doing well but that there was no GNSS signal?

In stead of sending the TSD as (possibly complex) tables one might consider the download of complete software modules to calculate the TAR by or on behalf the toll charger. This requires much more sophisticated OBE and also raises complex not yet resolved security issues.

An alternative architecture (not shown) is a one in which the TSD is not sent directly to the OBE but via the toll service provider. This alternative architecture looks only feasible when this data do not change very often.

3.7.4 Enforceability

The enforceability of this variant is equivalent to the enforceability of variant D.

3.7.5 Privacy

The privacy in this variant is equivalent to the privacy in variant D.

3.7.6 Performance

The performance of the variant is roughly comparable with the performance of variant D:

2. This variant makes better use of the OBE and therefore requires less processing capacity of the central toll charger equipment
3. The needed communication capacity for the TARs might even be less then for the D-LARs in variant D if the 'granularity' of the TARs is sufficient less than the 'granularity' of the D-LARs.
4. This variant requires downloading of TSD into the OBE.

3.7.7 Adaptability

As the production of TARs is more vulnerable for toll regime changes then the production of LARs, this architecture is more vulnerable to adaptations then the previous variants. On the other hand, changes of a tariff without changing the tariff scheme are part of the regular operational procedures and do not require any (serious) adaptation of the OBE.

3.7.8 Conclusions

This architecture variant might be a good next step after variant D. It does not seem to mature enough for a quick large scale implementation but might benefit from the current developments on dynamic map updates for route guidance.

The download of software from toll chargers on OBE under the responsibility of a toll service provider is considered to be still too complex. (See the forthcoming [View on OBE architectures]).

3.8 Variant G: Declarations from the OBE via the toll service provider to the toll charger

3.8.1 Process flow

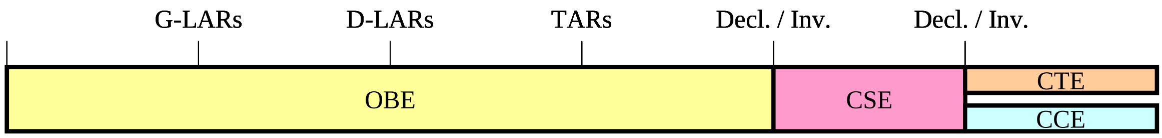


Figure 3-14 Process flow Variant G

3.8.2 Architecture

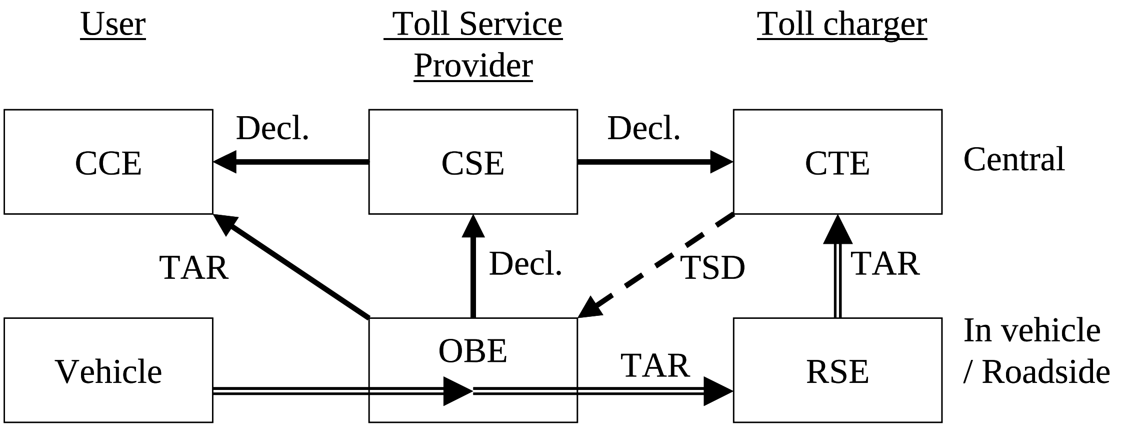


Figure 3-15 Architecture variant G

3.8.3 Description

In this architecture the OBE does not only calculate the TARs (see the description of variant F) but also draws up a complete declaration.

The TSD required now needs to include also the arrangement on when to generate a new declaration.

The declaration may or may not be itemized, i.e. may or may not include the TARs on which it is based. In the latter case the process in the OBE should be securely monitored (see below).

3.8.4 Enforceability

Enforceability depends on whether or not the TARs are included in the declaration.

If not, checks afterwards require that the toll charger may request the toll service provider or his customer at random (or in case of a suspicion) that he presents him the TARs and/or D-LARS for inspection. However in that case he should be sure that this list of TARs and/or D-LARs is not manipulated afterwards[43].

[43] Which can be accomplished quit easily by requiring that the declaration should contain a so-called hash-code over the list of TARs and/or D-LARs.

Enforcement may be accomplished by unobtrusive surveillance. The toll charger can then afterwards if the observed presence of the vehicle corresponds with the TARs he receives from the OBE or from the toll service provider or his customer.

Besides, RSE may interrogate the OBE by requesting copies of last recently produced D-LARs and/or TARs. However, in this case the toll charger must be sure that these TARs are actually correctly used the declaration[44].

Again, interrogating the OBE with checks afterwards is feasible when it is trusted that the behaviour of the OBE does not depend on its being checked[45].

3.8.5 Privacy

In case of itemized declarations the privacy is equivalent to the previous architecture F.

In case of non-itemized declarations (and a securely monitored OBE) the privacy protection is optimal. Both the toll service provider and toll charger do not receive more route information then necessary.

3.8.6 Performance

In case of itemized declarations the performance is equivalent to the previous architecture F.

In case of non-itemized declaration this architecture requires the least (international) communications capacity.

This architecture makes optimal used of OBE processing capacities.

3.8.7 Adaptability

As the production of declarations is more vulnerable for toll regime changes then the production of TARs, this architecture is somewhat more vulnerable to adaptations then the previous variants.

3.8.8 Conclusions

This architecture might become the preferred one if the techniques for the previous architecture F would become mature enough.

[44] This can be easily accomplished by securely adding the fees in the TARs and by including this sum securely into the declaration. In more practical terms, one might have a SAM, a secure application module, looked at all TARs once they produced, let this SAM calculate and sign the sum for the invoice.

[45] This can be easily achieved with the same SAM as used for calculating the sum for the declaration.

4. Summary of conclusions and recommendations

4.1 Summary of conclusions

Analyses of the architecture variants in the previous sections has led to the following conclusions:

A. G-LARs to the toll service provider, D-LARs to the toll charger

This architecture is quite feasible for next few years. Because of the simple OBE it can be implemented in due time and, in case the own OBE of a toll charger also performs some additional processing he only has to port this processing to his own central equipment.

Nevertheless it is expected that this architecture will be replaced gradually by ones that makes more use of the OBE capabilities (processing power) and requiring less (international) communication.

B. G-LARs to the toll service provider, TARs to the toll charger

This variant has no clear advantage when compared with variant A. Disadvantages are an ambiguous role of the toll service provider and the additional complexity of enforcement and adaptability.

Therefore, this variant is not advisable.

C. G-LARs to the toll service provider, declarations to the toll charger

This variant has no clear advantage when compared with variant A. Disadvantages are an ambiguous role of the toll service provider and the additional complexity of enforcement and adaptability.

When compared with the previous variant B, there is more room for a trade off between enforceability and privacy.

Nevertheless, this variant is not advisable.

D. D-LARs from the OBE to the toll charger

When compared with A this variant shows improved enforceability, improved performance, and improved privacy only at the expense of the need for downloading rough toll domain boundaries into the OBE.

Therefore, this architecture is preferred to variant A and should be used for all OBE in which the toll domain boundaries can be downloaded.

E. DSRC TARs from the OBE to the RSE

This architecture is well suited for the current interoperable DSRC systems.

Nevertheless the protocol for the communication between OBE and RSE may need to be revised if new toll regimes will use new vehicle parameters.

F. TARs form the OBE to the operator

This architecture variant might be a good next step after variant D. It does not seem to mature enough for a quick large scale implementation but might benefit from the current developments on dynamic map updates for route guidance.

The download of software from toll chargers on OBE under the responsibility of a toll service provider is considered to be still too complex (See the forthcoming [View on OBE architectures])..

G. Declarations from the OBE to the toll charger

This architecture might become the preferred one if the techniques for the previous architecture F would become mature enough.

Summarizing, it is expected that the interoperable architecture will support variant E for DRSC and will gradually evolve for GNSS from variant A, via variant D and F to variant G.

4.2 Recommendations

In order to be able to implement these architectural variant it is recommended to standardize (or specify otherwise) the exchange between the various equipment configurations of:

1. LARs, TARs, Declarations and invoices.

   A standard for the exchange of this data between the various parties is considered basic requirement for the introduction of an EETS.

2. enforcement / proof of passage data

   A standard for the exchange of this date is required to support the enforcement process. It maybe used for the exchange of proof of passage information between toll chargers and toll service providers. It should also be harmonised with the VERA2 eNFORCE proposals.

3. the description of the toll domain borders (the TDD in the architecture figures)

   Drafting of this standard may be part of the revision of the draft ISO 17575 standard.

4. The description of toll scheme data (the TSD in the architecture figures)

   For the longer term but still urgent if we want to use the results in time, it is recommended to standardise the exchange of TSD . Drafting of this standard may be part of the revision of the draft ISO 17575 standard.

Annex A. References

2004/52	Corrigendum to Directive 2004/52/EC of the European Parliament and of the Council of 29 April 2004 on the interoperability of electronic road toll systems in the Community (OJ L 166 30.04.2004), OJ L 200, 07.06.2004, p. 50
IEEEJ016	Standard for Information Technology, Software Life Cycle Processes, Software Development, Acquirer-Supplier Agreement (Issued for Trial Use) EIA/IEEE Interim standard J-STD-016-1995, September 1995
Mister2004	Wolfgang Beier e.a. MISTER, Minimum Interoperability Specification for Tolling on European Roads, Draft for comment, version 2.5, 24 November 2004. Distributed by: - CEN TC278/WG1/SG5 as document sg5388. - CEN TC278/WG1 as document WG1 N835 rev1.
View on OBE architectures	An example of a view on OBE architectures and tolling Jan Vis, forthcoming

Annex B. Tariff schemes and toll declarations

B.1 Introduction

This annex provides a description of the type of tariff schemes that should be supported within an EETS context and, consequently by the relevant standards[46]. It main purpose is identify the required complexity of the communication provisions for OBE that issues toll account records (TARs) for GNSSS based systems[47].

It also provides an overview of the toll declarations the OBE, depending on the architectural variant, has to issue. These declarations, when accepted, should also be supported by the relevant standards[48].

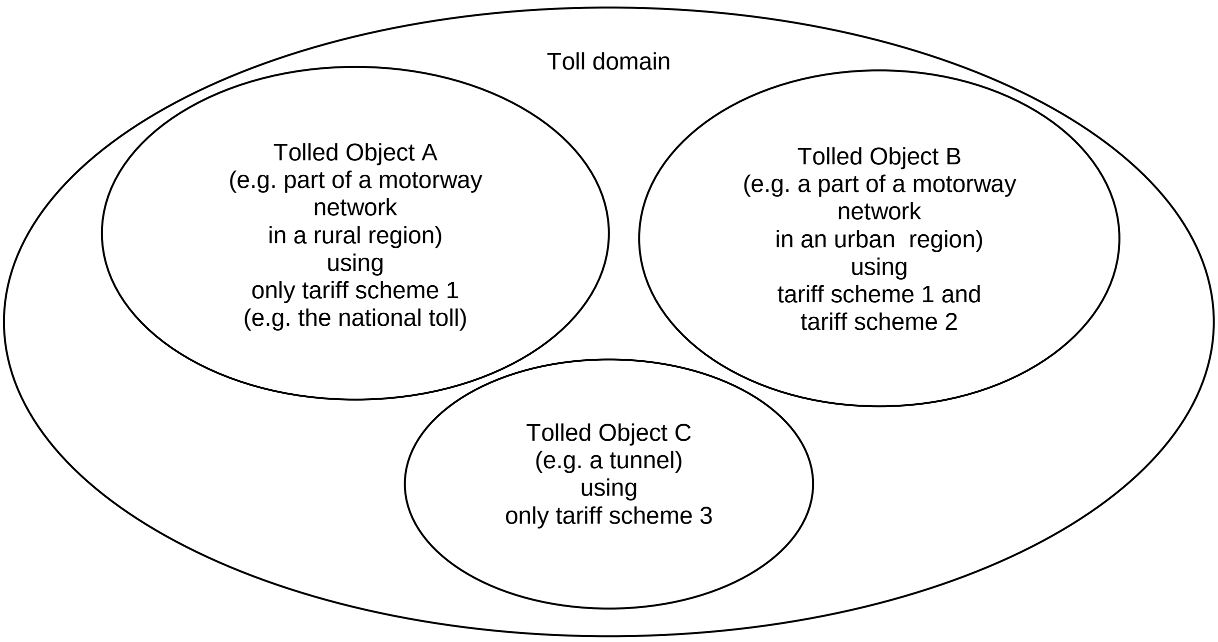
B.2 Tariff schemes

B.2.1 Basic characteristics

Generally speaking, the tariff in a toll domain:

1. may depend on the tolled object, the vehicle characteristics and the date-time of the presence of the vehicle
2. may be expressed as a fee per passage, per unit of time, or per unit of distance
3. may enjoy a discount

For one tolled object more than one tariff scheme may apply[49]. In case more than one tariff scheme applies, the total fee to be paid is the sum of the fee per tariff scheme. See the figure below.



[46] Like ISO CEN TS 17575 dealing with the communication between vehicles and central equipment using a cellular network.

[47]. Using technical terms, the more complex tariff schemes, the more complex the application protocol must be for the download of these tariff schemes as part of the toll scheme data (TSD).

[48] Like, again, ISO CEN TS 17575

[49] E.g. one for a national fee and one for a regional or local fee.

B.2.2 The tariff

B.2.2.1 Vehicle tariffs

A tariff for a vehicle may depend on a number of vehicle characteristics, which can be further subdivided into:

1. static declared characteristics (like the data in a vehicle registration certificate)
2. dynamic declared characteristics (like the presence of a trailer)
3. dynamic parameters measured within the vehicle. e.g. speed (not yet used)
4. characteristics measured by roadside equipment or from above the road[50].

In order to limit the complexity of the types of tariff schemes to be supported, it is required that for each tariff scheme all the relevant static and dynamic vehicle characteristics can be mapped to one vehicle tariff class parameter[51] with distinct values.

Requiring distinct values excludes tariff schemes in which the fee is a continuous function of one or more vehicle parameters, e.g. a fee that proportional to the weight or proportional to the square of the speed. However it includes tariff schemes in which the fee depends on value classes of such parameters.[52].

As a rule, the same toll is levied at the same time for the same tolled objects for any two vehicles with the same vehicle tariff class.

B.2.2.2 Tolled objects tariffs

Within a toll domain it is assumed that:

1. Toll will be levied per the tolled object, (e.g. per (stretch of a) road, city centre, a bridge, a ferry, etc)
2. Toll may be levied while the vehicle is roaming through a tolled object or at one or more toll points within the tolled object or at its border.
3. Per tolled object one or more tariff schemes apply (e.g. one for a national toll and one for a local toll)
4. Different tariff schemes for a tolled object may be based on different vehicle characteristics[53]

In order to limit the complexity of the types of tariff schemes to be supported, it is required that each tariff schemes for a tolled object in a toll domain can be represented by a single tariff scheme number only[54].

As a rule, under any toll tariff scheme the same toll is levied at any time for all vehicles with the same vehicle tariff class.

B.2.2.3 Date and time dependence

For each vehicle tariff class within a tariff scheme the fee levied may depend also on the date and time.

---

[50] Parameters measured from the road side (e.g. the height of a vehicle above the first axle) are used for DSRC, see ISO 14096, but do not seem to be required for systems using GNSS and cellular networks.

[51] This excludes e.g. complex schemes in which the fee is based on some combination of two parameters, one parameter depending on a distance driven and the weight of the vehicle and the other parameters depending on the time of the day and the Euro class of the vehicle.

[52] In most cases it may be sufficient to define a reasonable number of suitable classes. If not dynamic, also the value (e.g. the max authorised laden mass in units of 10kg) might be used as the vehicles tariff class.

[53] Consequently, each tariff schemes may assign another vehicle tariff class to a vehicle.

[54] This excludes schemes in which the fee depends on a dynamic tolled object related parameters, like e.g. traffic density.

In order to limit the complexity of the types of tariff schemes to be supported, it is required that the dependence on the date and time can mapped to a sequence of periods each having a constant fee during the wholes period.[55, 56.]

In order to limit the complexity of the types of tariff schemes to be supported, it is required that for each tariff scheme all the relevant static and dynamic vehicle characteristics can be mapped to one vehicle tariff class parameter[57] with distinct values.

B.2.2.4 In summary

For each tolled object in a toll domain one or more tariff schemes may apply.

Each toll scheme used in a toll domain may be represented by a single tariff scheme number.

The fee levied for a vehicle tariff class under a certain tariff scheme only depends on distinct periods of date and time.

B.2.3 The fee per unit

For the EETS one should allow tariff schemes using either a fee:

1. per passage of the vehicle, or
2. per unit of distance driven through a tolled unit, or
3. per unit of length of stay in a tolled unit

For the length of stay, the unit may already have been started before the vehicle enters the tolled object. This may be the case e.g. if the length of stay is measured in calendar days[58].

A fee depending on the length of stay may be limited to a maximum per period[59].

In case the fee is levied per unit of distance or length of stay, the units may be rounded in several ways:

1. proportional to some fraction of the units or fraction of the fee (e.g. per 100 meter or per cent).
2. to complete units (and for the length of stay also to a complete first unit[60])
3. rounded, i.e. with the number of units rounded to the nearest integer.

TEMP EXAMPLE Support of EG9 results

The table below shows how the 'basic types' of toll schemes as distinguished in the EG9 report relates to the toll schemes supported.

EG9 toll class	Propsed ISO CEN TS17575 tariff scheme
Measured distance toll	A flat tariff per unit of distance (and independent of the date and time) for a toll object that encompasses a complete area (public and private roads and terrain)

[55] This exclude tariff schemes in which the tariff is a continuous function of the time. Like,. a fee which is proportional to the time in a particular period, e.g. at the beginning of a rush hour.

[56] Nevertheless the tariff may depend on the length of stay in a toll tolled.

[57] This excludes e.g. complex schemes in which the fee is based on some combination of two parameters, one parameter depending on a distance driven and the weight of the vehicle and the other parameters depending on the time of the day and the Euro class of the vehicle.

[58] This is e.g. the case in London.

[59] A fee per hour may be limited to maximum fee per calendar day, as is sometimes the case for parking.

[60] In case of a tariff based on complete units of length of stay within an area, one has to consider the exemption of vehicles parked or garaged on private property for one of more complete units.

Road segment toll	A tariff per passage of a tolled object, e.g. a road segment, a bridge, a ferry, a tunnel, or a cross section of a road (e.g. as part of a toll plaza).
Road segment toll with a fee proportional to the length of the segment	When a road network that is completely partitioned in non-overlapping segments, a tariff per unit of distance for a toll objects can be levied as a toll per segment (like the LkW-maut in Germany)
Closed network toll	A tariff per route between two toll points, i.e. an entrance and a exit cross section (e.g. as part of a toll plaza) of a closed network of toll roads.
Cordon toll	A tariff for an area levied at toll points at its border, e.g. a cross section of a road. The tariff may depend on the direction.
Cordon toll where some specific combinations of entry and exit points are charged differently	A tariff for an area levied at toll points at its border superimposed with a tariff for some pairs of toll points.
Area toll (for staying, not in EG9)	A tariff per calendar unit of length of stay within a toll object that encompasses a complete area (public and private roads and terrain). Each unit, e.g. a day, is charged completely and a vehicle may leave and re-enter the area within that unit.
Area toll (for driving)	Like the area toll for staying, but only levied when the vehicle was driving within the unit of length of stay.
Time-based toll	A tariff per unit of length of stay where the fee is proportional to the length of stay.

(end of temp example)

B.2.4 Discounts

Discounts can be based on all kinds of criteria and the calculation of discounts in a vehicle is therefore difficult to support[61]. However, in case of fee reductions, a toll charger may decide to provide the vehicle with a vehicle tariff class that reflects the discount.

In all other cases, the toll charger should calculate the discount when the invoices are issued.

B.3 Toll declarations

B.3.1 Introduction

Electronic toll fee collection is based on a toll declaration issued by the OBE and providing the toll charger with an valid and undisputable claim for the fee due.

Considering the various architectures the following toll declarations should be supported:

1. location account records without road map matching
2. location account records with road map matching << not yet in draft ISO CEN TS 17575 >>
3. toll account records without fee calculation
4. toll account records with fee calculation
5. toll declarations to be paid without awaiting an invoice << not yet in draft ISO CEN 17575>>.

The data for these records is further specified in the following sections[62].

The data in these records may also be used for the items in an itemized invoice.

B.3.2 Location account records without road map matching

[61] Also, draft ISO TS 17575 does not support discounts.

[62] Of course, the encoding of this data should be optimised if more records are transmitted at the same time.

In this case the OBE only declares the presence of the vehicle at a certain geographic location at a certain time. A location account record contains then the following data:

1. the account number of the vehicle
2. the date and time (including the difference with UTC)[63]
3. the geographic location of the vehicle
4. the total distance driven with the vehicle (the odometer reading)

Location account records without road map matching may produced at any time or distance interval and may be (collectively) submitted at any time or distance interval encompassing one or more production intervals.

B.3.3 Location account records with road map matching

In this case the OBE declares the presence of a vehicle on a particular road within a toll domain at a specific time. However, the OBE of the vehicle is unaware of the presence of tolled object and the toll regime in the toll domain.

A location account record contains then the following data:

1. the same date as for location account records without map road map matching, plus
2. the identification of the (stretch of a) road, if appropriate[64]

Location account records with road map matching may produced at any time or distance interval and may be (collectively) submitted at any time or distance interval encompassing one or more production intervals.

B.3.4 Toll account record without fee calculation

In this case the OBE declares the number of 'toll fee units'[65] that has to be paid for the presence of the vehicle in a toll domain.

A toll account record may contain then the following data:

1. the same date as for location account records without map road map matching, plus
2. the vehicle tariff class
3. an identification of the tolled object for which the fee has to be paid
4. optionally, the identification of the (stretch of a) road, if appropriate << for further study >>
5. the amount of 'toll fee units' that has to be paid since the previous toll account record for that tolled object and that tariff scheme.
6. the cumulative amount of toll units to be paid (e.g. on the same invoice), optional

Toll account records may produced at any time or distance interval or while passing or leaving a tolled object. They may be (collectively) submitted at any time or distance interval encompassing one or more production intervals or when passing or leaving a tolled object.

B.3.5 Toll account records with fee calculation

In this case the OBE calculates the fee that has to be paid for the presence of the vehicle in a toll domain.

A toll account record may contain then the following data:

---

[63] To avoid ambiguities at the end of a summer time period,

[64] The relation between tolling and road maps still requires further study. ISO 17571 might be suitable.

[65] Similar to the ´ticks´ used former day by telephone companies.

1. the data elements a), b), c) and d) for toll account records without fee calculation plus
2. the fee that has to be paid since the previous toll account record for tolled objects with the same tolled object tariff class.
3. the cumulative amount of fee to be paid (e.g. on the same invoice), optional

B.3.6 toll declarations to be paid without awaiting an invoice

In this case the OBE sends a declaration that has to paid without awaiting an invoice from the toll charger.

Such a declaration may be issued e.g. monthly, or when the vehicle leaves the toll domain, or when the fee to be paid exceeds some threshold[66,67].

Such a declaration may contain the following data:

1. the account number of the vehicle
2. the date and time (including the difference with UTC) of the start and end of the period
3. the hash code over all toll account record relating to this period[68]
4. the total distance travelled during the period in the toll domain
5. the total amount of fee to be paid for the period

In addition, the toll charger may request to receive the toll account records relating to this period as well. E.g. via a CN, as supported by this part of ISO CEN TS 17575, or via separate means, not

[66] Such a scheme may be very attractive: the communication costs are minimal and the invoice costs are avoided.

[67] The scheme may look problematic when a toll service provider 'buys toll' for wholesale prices, i.e. at a price his customer has nothing to with. On the other hand, the fee calculated by the OBE may be a 'nominal' one and the lower 'wholesale price' may also be calculated later as a discount for the toll service provider on this nominal fee.

[68] One may under this scheme allow the OBE not to send but only to retain a list of toll account records for later inspection when needed. The hash code can then be used to verify that this list has not been changed,

Annex C. Terms, definitions and abbreviations

C.1 Terms and definitions

accepted toll declaration
a toll declaration that is not contested by the toll charger

NOTE: A valid tolling declaration may still contain incorrect data, e.g. a wrong declared parameter or a wrong vehicle location.

actor
a person or legal entity who performs or takes part in any action; a doer.

central account
an account that is kept and administered off-board.

contract issuer
CEN TC278/WG1 term for toll service provider, see toll service provider.

customer (of a toll service provider)
a person or legal entity who uses the service of a toll service provider.

NOTE Depending on the local situation the customer may be the owner, lessor, lessee, keeper, (fleet) operator, holder of the vehicle's registration certificate, driver of the vehicle, or any other third person.

declaration
a statement drawn up by or on behalf of the toll service provider of the toll fee sum due based on the list of TARs for some period.

NOTE 1 A declaration may or may not be itemized, i.e. may or may not contains the TARs on which it is based.

NOTE 2 A declaration may or may not contain also service fees, e.g. to be due to the toll service provider.

driver
a person who drives a vehicle.

NOTE The driver is assumed to operate (use / serve) the OBE (e.g. the setting of the number of axles).

EETS (European Electronic Toll Service)
A service enabling users having only one contract and one set of OBE to use a vehicle in all toll domains under the operation if Directive 2004/52.

EETS provider
A toll service provider providing toll services for all toll domains under the operation of EU directive 2004/52.

EFC Operator
CEN TC278/WG1 term for toll charger, see toll charger

electronic fee collection (EFC)
toll charging by electronic means via a wireless interface.

NOTE The actual payment (collection of the fee) may take place outside the toll system.

enforcement
the process of compelling observance of a law, regulation, etc.

NOTE In this context: the process of compelling observance of a toll regime.

equipment interoperability
the ability of two or more pieces of equipment to operate in conjunction

interoperability
the ability to operate in conjunction (see the SOED)

invoice
a statement drawn up by or on behalf of the toll charger of the toll fee sum due based on the list of TARs for some period.

NOTE 1 An invoice may or may not be itemized, i.e. may or may not contains the TARs on which it is based.

NOTE 2 An invoice may or may not contain also service fees, e.g. to be due to the toll service provider.

toll service provider
a person or legal entity providing to his customers toll services on one or more toll domains for one or more classes of vehicles.

NOTE 1 The toll service provider may provide the OBE or may provide only a magnetic card or a smart card to be used with OBE provided by a third party (like a mobile telephone and a SIM card can be obtained from different parties).

NOTE 2 The toll service provider is responsible for the operation (functioning) of the OBE.

non-repudiation
in this context, the property that neither the toll service provider nor the toll charger can deny in all or in part the participation of their OBE respectively toll system in a communication (see ISO 9498-2)

onboard toll equipment (OBE)
equipment fitted within or on the outside of a vehicle and used for toll purposes.

NOTE 1 The OBE does not need to include payment means.

NOTE 2 See also onboard toll unit

onboard toll unit (OBU)
onboard toll equipment assembled in one monolithic device.

one(s) liable for toll
natural or legal person(s) liable to pay toll under the operation of a toll regime.

NOTE A toll regime may designate more than one person to be (jointly and severally) liable for the paying the toll.

operator
Directive 2004/25 term for toll charger, see toll charger

organisational interoperability
the ability of two or more person or legal entities to operate in conjunction

NOTE the ability of organisations to operate in conjunction includes, if applicable, the interoperability of their equipment.

toll
a charge, a tax, or a duty in connection with using a vehicle within a toll domain.

TEMP NOTE The definition is generalization of the classic definition of a toll as 'a charge, a tax, or a duty for permission to pass a barrier or to proceed along a road, over a bridge, etc.'. The definition above also includes fees regarded as an (administrative) obligation, e.g. a tax or a duty.

toll charger
Proposed Cesare III term for toll charger, see toll charger

toll declaration (from OBE)
a statement (from the OBE of a vehicle) to a toll system confirming the presence of a vehicle in a toll domain in a format agreed between the toll service provider and the toll charger

NOTE A valid toll declaration has to the fulfil formal requirements, including security requirements, agreed between the toll service provider and the toll charger.

toll domain
an area or part of a road network where a toll regime is applied.

toll charger
a public or private person or legal entity charging toll for vehicles in a toll domain.

TEMP NOTE Directive 2004/52 uses the term operator and sometimes road toll charger. Cesare III has proposed the tem toll charger instead and CEN TC278/WG1 uses the term EFC operator.

toll point
A point, a cross section of a road, in a toll domain where the OBE must issue an toll declaration.

EXAMPLE A part of toll plaza for electronic fee collection.

toll regime
the set of rules, including enforcement rules, governing the collection of toll in a toll domain.

toll scheme
a generic term used for toll regime and/or toll domain and/or toll system depending on the context.

toll service
a service enabling users having only one contract and one set of OBE to use a vehicle in one or more toll domains.

toll system
the off board equipment and possible other provisions used by a toll charger for the collection of toll for vehicles.

NOTE 1 The OBE is excluded from the definition. If not, OBE should be part of any toll system for which it may be used.

NOTE 2 The actual payment (collection of the fee) may be take place outside the toll system.

tolled object
a distinguished part of a toll domain.

NOTE A tolled object may be e.g. a bridge, a zone, or a stretch of a road (network).

valid toll declaration
a toll declaration that provides the toll charger with a valid claim for the fee on the toll service provider and/or its customer.

NOTE Valid communications has to fulfil formal requirements, including non-repudiation requirements, agreed between the toll service provider and the toll charger.

user
a generic term used for the customer of a toll service provider, one liable for toll, the owner of the vehicle, a fleet operator, a driver etc. depending on the context.

C.2 Abbreviations

CCE Central Customer Equipment

CEN	Comité Européen de Normalisation
CSE	Central toll Service provider Equipment
CTE	Central Toll charger Equipment
Decl.	Declaration
D-LAR	Toll Domain specific Location Account Record
DSRC	Dedicated Short Range Communications
EETS	European Electronic Toll Service
EU	European Union
G-LAR	Generic Location Account Record
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HGV	Heavy Goods Vehicle
Inv	Invoice
LAR	Location Account Record
OBE	Onboard Equipment
RSE	Road Side Equipment
SAM	Secure Application Module
TAR	Toll Account Record
TDD	Toll Domain data
TSD	Toll Scheme Data (Toll Domain plus tariff data)