Integrated Modelling of Business Processes and Communication Events for Public Transport

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Abstract. In this paper, a generic communication system, which is controlled by a formalized process model is proposed and instantiated for the public transport domain. The operation of this system combines a distributed workflow model (Business Process Modelling Notation, BPMN) with open communication standards such as real time communication (RTC) characteristics as provided by e.g. LTE mobile IP networks. The performed formalization meets the requirements of a typical scenario in public transport: connection protection. The participants involved are represented by control centers, along with the vehicle users: driver and passengers. Formalization with BPMN allows the modelling and understanding of the different interactions and communications between the different agents. For public transport operators the approach set out in this paper leads to a considerable advantage regarding economic requirements.

1 Motivation

One of the most crucial requirements for reliable and efficient operation of public transport is the knowledge of all information about any incidence which takes place during an operation day – and, of course, in real time. For instance, delays, accidents, road work, or special events. In order to perform the most favorable solution, the necessities and requirements of the passengers must be taken into account. To achieve this, the availability of an accurate communication between control centers and vehicles, as well as between vehicles, is a fundamental requirement. Current state of the art has some disadvantages.

The use of *dedicated communication infrastructure* (analog mobile radio, digital mobile radio systems, special mobile infrastructures…) is economically disadvantageous [8]. The utilization of public mobile networks is desirable.

The technology of public transport consists of *heterogeneous systems* with proprietary interfaces. It would be desirable to unify and standardize these systems by means of a unique and public general process language. This language should provide high level tools, capable of being integrated with the low level systems from each company. Moreover, they should facilitate the development of graphical user interfaces, easily handled by any user.

The *lack of process integration* in a proper workflow can cause a considerable loss of information. The use of a suitable modelling environment allows the correct and complete representation of all the process phases. In this way, the identification of the possible problems and their solution is facilitated.

2 Application example: Connection protection in public transport

Missing a connection because of a delayed trip is a very important problem which passengers of public transport have to deal with. Connection protection manages these kinds of situations, dealing with the decision of waiting for the connecting passengers from one delayed feeder vehicle. It can provide a very important and necessary solution on the critical situations of public transport availability. These kinds of situations can be measured according to *spatial* factors (*where* services are less frequent, like in rural areas), along with *temporal* factors (*when* services are less frequent, like in evenings). However, connection protection is a complicated optimization problem, characterized by a trade-off between time losses incurred by transit passengers not leaving the vehicle and connecting passengers changing between vehicles. For a proper operation of the system, an *explicit, unambiguous, correct* and *complete* process definition (what needs to be done by whom) is needed. This is facilitated by the use of formal methods in process design which has the following advantages:

- *Explanatory function:* simply formulating and documenting "how things are done" within an organizational framework makes a direct contribution to repeatably deliver good service quality. *Graphical notations* support communication and understanding by all associated stakeholders.
- *Formalization* with the associated benefits of analytics (e.g. verification) contributes to the stabilization of the processes.
- *Disambiguation:* operator errors can be reduced and an optimal user experience even under accident conditions can be guaranteed as all eventualities are covered in the process definition.

Business processes can be seen as an orchestrated and repeatable pattern of business activities enabled by the systematic organization of resources into processes that provide services. Processes can be depicted as a sequence of operations and declared as work of a person or group within an organization or across organizational boundaries. Different graphical representations of work flows are available (e.g. *UML activity diagrams*, *Event-driven process chains* (EPC) as well as *work flow Petri nets* [9]). All of them are frameworks of token-based semantics allowing to define and automate distributed processes. For the given application in the public transportation domain the decision was made to use the Business Process Model and Notation (BPMN).

The first reason is the *availability of process definition tools*. Tools with graphical user interfaces allow to define workflow processes in an intuitive and simple way. Furthermore the powerful analysis techniques (and simulations) Petri net theory provides for the verification of the correctness of workflow procedures tools can be used as tool chains allow to translate BPMN to Petri nets and back [9].

The second reason is *expressiveness.* BPMN supports control flow behavior as well as interaction behavior and data flow. Therewith it is not only used for processes within one company, it is also used for modeling interaction processes of multiple companies or organizations [9]. BPMN allows the formalization of distributed and interacting processes carried out by different agents. The manifoldness of interactions between them is uniquely represented by interchanged messages. This is very useful for the proper representation of the connection protection application example. In connection protection, several agents take part (control centers, drivers, passengers…), and the performed tasks by every agent are completely and correctly defined and differentiated. Through the development of "Internet-of-Things" there are more and more devices that can be on-line accessed, which supposes a great opportunity for its use in the public transport field. For instance, in the project IP-KOM-ÖV [1] an IP based communication service for public transport is deployed. However, a proper integration with the application level is missing. This is precisely solved in the proposed system by using a modeling with BPMN.

3 Formalization using BPMN modeling

BPMN [2] is a standard specification developed by Business Process Management Initiative (BPMI) in 2004 [3] and subsequently maintained by Object Management Group (OMG) (merged with BPMI) since 2005 [4]. From March 2011, the current version is 2.0. BPMN models are represented by means of Business Process Diagrams (BPDs). The BPD associated to the proposed system contains the following elements:

1. Pools: each pool depicts one participant in the whole system, and is associated to an executable process.
2. Tasks: are represented with a rectangle. They mean any activity to be done. "Send tasks" are specific cases, which are utilized to send messages from one process to another.
3. Exclusive gateways: are represented with a diamond shape and a cross inside. When the process reaches a gateway, a specific condition is evaluated. The result determines the path to be followed.
4. Events: are represented with a circle. They mean anything that happens. In the proposed model, 3 kind of events are used:
    a. Receive events (symbol: envelope): a message from another participant is received.

b. Timer events (symbol: timer): the process sleeps during certain time (set by a timer), and then it continues.
c. Signal events (symbol: triangle): in order to initiate the execution of a sub-process, a process triggers a “throw” signal event (filled triangle), which is caught by the sub-process by means of a “catch” signal event (empty triangle).

In the proposed system, a business process with seven participants is modelled [6][7]. Thus, a collaboration diagram, composed of seven pools, is shown. Three kinds of messages are interchanged between the participants. In order to make the representation easier, a two-letter code is associated with each participant and message:

Participants.
1. **Bus (Feeder/Connecting) [BF/BC]:** Vehicles involved. Each one of them sends regular real time updates to its corresponding ITCS.
2. **ITCS (Feeder/Connecting) [IF/IC]:** Intermodal Transport Control Centers. They manage the incidents for their corresponding buses.
3. **ITIS [IT]:** Intermodal Transport Information System. It contains all the information related to schedules, and responses to passenger requests.
4. **Passengers (Feeder/Connecting) [PF/PC]:** They interact with ITIS

Messages.
1. **Real-time update [RT]:** sent from each bus to their corresponding ITCS, it contains information about the current position and predicted arrival time.
2. **Decision [DC]:** the decision of wait, or not, for the delayed feeder bus, is taken by the ITCS connecting, and then forwarded to the other participants.
3. **Trip planning [TP]**: it is requested by the passengers to ITIS. It contains all the information about a trip, such as bus lines and schedules

In order to name the different, a message code is used in the following way: SS_RR_MM. Where, SS represents the sender, RR the receiver, and MM the message code. For instance, the code IC_IT_DC represents a message sent from ITCS (Connecting) to ITIS, which contains a Decision.

3.1 Sub-model 1: Interaction between ITIS and passengers

The process begins when the passengers intend to make a trip, and make a request to ITIS, which answers them with a Trip Planning (TP) message. Moreover, whenever there is a change (delay or decision to wait) in the planned time schedule, ITIS is informed, and subsequently sends a notification to the passengers involved in the affected trips.

3.2 Sub-model 2: Interaction between ITCS and buses

Each bus sends regularly real time information about its position and predicted arrival time to its corresponding ITCS. If a relevant change is detected, the ITCS forwards this information to ITIS and to the other ITCS, which forwards in turn to its corresponding bus.

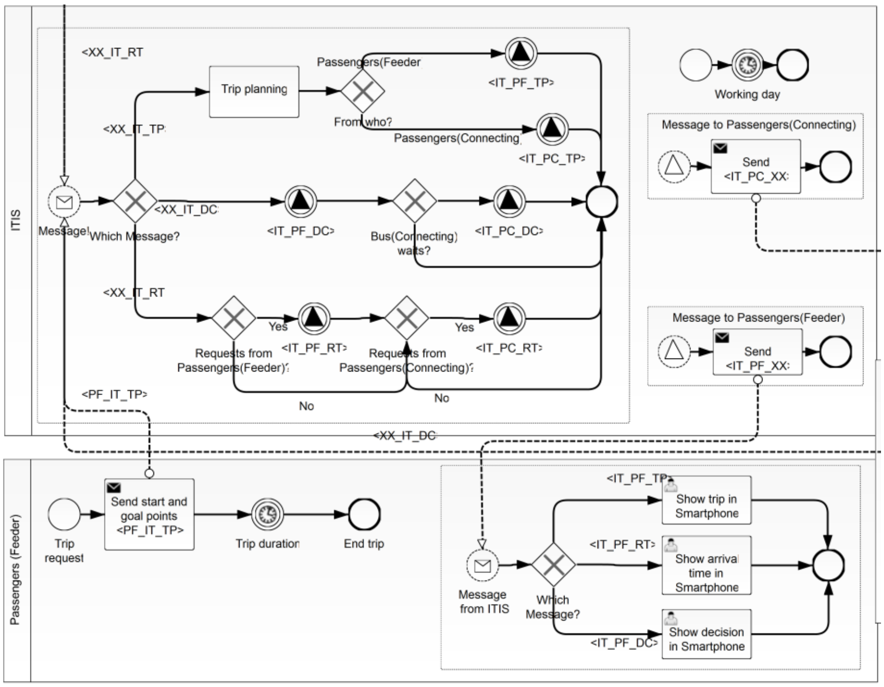

Fig. 1: Sub-Model 1: Interaction between ITIS and passengers (Feeder bus)

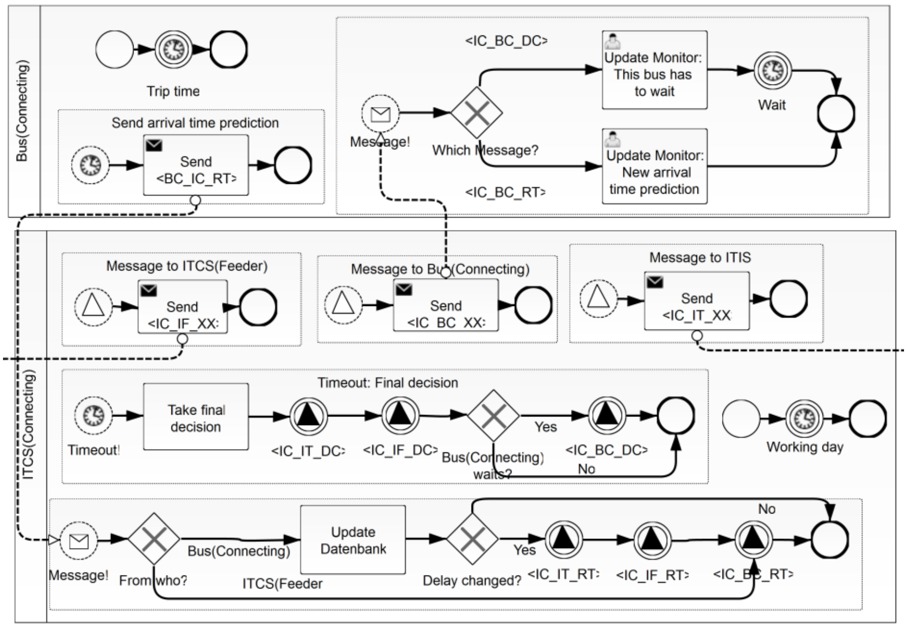

Fig. 2 Sub-Models 1 and 3**:** Interaction between ITCS and Bus including decision

3.3 Sub-model 3: Decision

The decision of waiting, or not, for the passengers from a delayed feeder bus is taken by the ITCS (Connecting). Then, this decision is forwarded to ITIS and the ITCS feeder. In case that a waiting has been decided, the connecting bus is also informed.

4 Heterogeneous networks: problems and solutions

In public transport, most of the involved agents are mobile. Therefore, they need a communication system enabling them to communicate between each other, regardless of time and location. The IP protocol is considered to be used in the future in every communication, from any kind of source (video, voice or data). Voice will be not only the most used source in communications, but also an essential part of the IT workflow. Therefore, several technical restrictions must be taken into account:

*Real-time restrictio*ns: voice communication requires real-time communication (RTC) which needs to be guaranteed in IP networks.

Interoperability restrictions: this is a very common problem in regional transport. The presence of different companies using IT can cause interoperability problems.

High variability restrictions: the mobility can cause connection losses, along with the addition of a considerable latency in the communication.

Secure data transmission: many applications in public transport require transmission of sensitive data. For example this is the operational status of vehicles, verification information for electronic ticketing and voice communication between vehicles and the operations control center. Especially in open networks such as the internet it needs to be ensures that security function will not be compromised by third parties [8].

1.1 Open vs. proprietary standards

An important aspect of the proposed system is the use of open communication standards, developed by several different authorized stakeholders and standardized by organizations like IETF (Internet Engineering Taskforce), ETSI (European Telecommunication Standardization Institution), 3GPP (Third Generation Partnership Project), etc. This is a considerable advantage, due to the possibility of acquire different improvements from each single provider. Specifically, the open standards CEA (Communications Enabled Applications) and Real Time Communication (RTC) give rise to significant potential for product and process innovation – not only in the public transport domain. WebRTC is an open standard for real-time communication which is currently being standardized by the World Wide Web Consortium (W3C). It enables applications with high demands on the real-time capability (voice over IP, video streams, etc.) within a web browser. WebRTC is used for recording, coding and (peer-to-peer) real-time transmitting multimedia content between web browsers.

1.2 Communication system architecture

We propose a communication system for public transport, which utilizes open standards [6][7]. For its implementation, a three-component architecture is proposed, as it can be seen in Fig. 3. There are three user interfaces: bus driver user interface, control center user interface, and passenger user interface. All of them run as Web GUIs. For any mobile application, a proper RTC-enabled mobile IP-based communication (layer 3) must be established. In order to achieve a reliable communication, several factors must be taken into account (bandwidth prediction, Quality-of-Service (QoS) and secure data transmission). In order to ensure secure communication data to be transmitted needs to be encrypted and/or transmitted via virtual private networks (VPN). A virtual private network is a logical network which is closed to outsiders, which bases on layer 3 of the OSI reference model and uses tunneling mechanisms for IP-based data transmission [8].

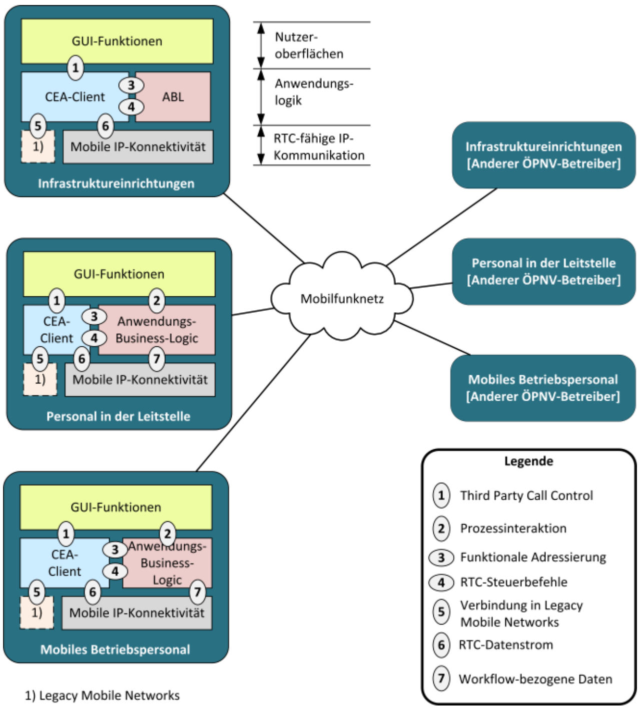

Fig. 3 Communication system architecture

The use of web technologies in communication architectures allows the developments of multiple operative models, such as "cloud computing" or "Software as a service". By means of the use of these resources, the public transport operators can save on certain costs of acquisition and operation, since they can delegate these activities to external IT providers. In the medium term, all the mobile IP communication will be deployed by means of broad bandwidth LTE networks. Mobile Virtual Network Operators (MVNO), which do not own their physical networks, but rent them to external operators, offer certain typical services, such as group calls [5]. Moreover, on the dedicated IP connections, the prioritization services can be offered, along with the Quality-of-Service parameters. It is necessary to develop migration scenarios during a transition period, in which the integrate use with conventional radio networks (both digital and analogic) can be possible. For this reason, several restrictions must be taken into account, such as the option of “non-IP connection” on the “Formalized Application Business Logic” (Fig. 3).

5 Conclusions and future works

This paper describes formal business process modelling for public transport business processes fully integrating with communication services for a highly distributed environment. The communication is performed using the IP protocol, which supposes an advantage for the use of this system on the field of Internet-Of-Things. The system has been developed by means of open standards, such as RTC and CEA, and formalized using BPMN. This formalization allows a clear design and understanding in order to translate the process design into an executable system. Documentation of a formalized but nevertheless understandable process model facilitated discussions with stakeholders allowing them to contribute their process knowledge in the specification phase. Further work should focus on formal verification in order to ensure completeness and correctness of the modelled processes.

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