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T4 – Telematics for Totally Transparent Transports

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Abstract— Transports can be made safer, more secure and efficient by help of telemetry and tracking on-line in real time. T4 is a system architecture aimed to support the development of telematic services for transparent tracking and surveillance monitoring of goods transported by different means on a global scale. The main idea is to focus on the transported pallets or parcels instead of the vehicles moving them. To enable rapid response to new customer requirements and to support remote management of field equipment, software implemented services are designed, packaged, deployed and mediated using XML, Java and the OSGi software technology standards.

I. INTRODUCTION

IN this paper we describe a system architecture called T4 intended for cost effective, scalable, multi-modal, telemetry and tracking of individual cargo items using Active-RFID and telematics technology. T4 is specifically designed to support cooperation between multiple small-scale international transport operators and to be an integrated part of Intelligent Transport Systems (ITS) and Traffic Management Systems (TMS) as discussed in [1] and [2].

New functions, e.g. based on GPS [3], added to smart cellular phones and handheld computers, enable new services to be created. Information services accessed via such terminals in vehicles are referred to as telematic solutions.

Several companies have discovered the advantages of using telematic solutions in order to improve their efficiency, and to offer their customers better or new services. Although telematic applications are simple in concept, they are complex in terms of the many technologies involved. The applications have often suffered from interoperability problems and have been bound to specific platforms. The market has therefore demanded an integration and interoperability standard to work within (a standard that at least enables modularity and component reuse). A couple of promising standards have also evolved, of which OSGi (Open Service Gateway initiative) [4] is one.

The OSGi standard offers a flexible and robust way to construct and run multiple services (application components) connected via different communication interfaces. This standard was created for the residential gateway market, but has evolved and is now suitable also for telematic systems.

The purpose with the T4 architecture is to provide a framework for tracking, monitoring and control of individual goods items as part of larger cargo transport chains using remotely accessible and controlled wireless sensor networks. T4 enables continuous unbroken service throughout the

whole transport chain including reloading of the goods at different intermediate terminals.

By utilizing existing infrastructure such as the fixed and mobile telephone networks as well as data networks, e.g. the Internet, in combination with Active RFID or radio equipped sensors (also called motes, [5]) attached in direct connection to parcels or pallets, new cost saving services are enabled.

T4 is based on telematic-oriented software and service technology combined with the use of wireless sensor network technology. The concept includes methods for service development, distributed service delivery and flexible adaptation to different customer needs. By using open standards and technologies these services can be offered also to small companies. Services that are comparable with or better than what large companies (which cover the whole transport and logistics chain) offer today. And T4 is also compatible with existing and complementary systems.

Services provide access to data originating from the sensor network. These services are offered to all actors in a logistics chain from producers via order, packaging, transport, drivers, to the final customers/receivers of goods. By enabling a more optimal and supervised delivery chain both environmental and other society gains can be achieved.

The T4 architecture is evaluated from a system and usage perspective in a demonstration project T4D (Telematics for Totally Transparent Transports – a Demonstration Project).

T4D integrates the above mentioned technologies, and makes it possible to illustrate and evaluate real world settings similar to those mentioned in Section 2. In this way the opportunities and the viability associated with the full system concept, as well as individual parts of the technology can be demonstrated and evaluated. T4D is a platform intended to enable research on specific problem areas as well as research on the system architecture level. T4D is also a prototype that can be evaluated by potential users and customers of the services. By testing the system in the real world, together with representatives for the whole chain involved in a transport service, we increase the knowledge about application requirements. This will help us to adapt the solution to these requirements and get advantage of potential opportunities.

The demonstrator T4D includes: active radio equipped sensors, mobile access points, smart mobile phones and/or PDAs used as user interface, and a service gateway connecting service providing servers and databases. The services that will be demonstrated are: tracking and logging of goods; real-time communication with goods, sensors and vehicle drivers; monitoring of environmental regulations or insurance requirements; and integration with existing systems.

II. APPLICATION SCENARIOS

In order to illustrate some of the opportunities with the proposed architecture and the technologies that it is based on, we describe two scenarios. In the first scenario tracking of cargo from departure to arrival is described. In the second scenario we add temperature and acceleration sensors monitoring what happens to the cargo during its transport.

A. Scenario One

An agency in Lund has promised that a parcel for Ericsson should be delivered to an exhibition in Milan and be there at the latest 1800 the same day as the exhibition begins.

Anne at the agency orders, via a web-interface, a transport from a transport company and receives an alphanumeric ID to attach with the parcel. Anne then gives Anders, member of Ericsson exhibition staff, an ID so that he also can access the tracking service. When the parcel is fetched by the transport company it is marked with an Active-RFID tag that contains the ID to be used for the parcel during its travel.

The transport company has no trucks planned to visit Italy, so another transport company is hired as a subcontractor. This subcontractor has goods to deliver to customers in Köln before continuing to Milan. By mistake the parcel is off-loaded in Köln and when the truck leaves an alarm is activated. A few minutes later the driver is asked to return to the loading terminal and after having fetched the parcel the transport can continue to Milan.

At 1500 on the day of the planned arrival, Anders has started to wonder where his exhibition material is. By use of the ID he got from Anne he can see that the parcel is in Italy and is predicted to arrive at the exhibition within 2 hours.

B. Scenario Two

The farmer Johnsson living close to Motala, a small town in Sweden, has purchased sheep from another farmer living outside Hamburg. When all paper work is done he gets in contact with the transport company Happy Animals, which is specialized in transporting animals within EU. Happy Animals accepts the transport task.

In his home in Motala, Johnson can follow the transport and see that the animals are in a good condition when loaded on the truck. During the travel the driver decides to stop and have lunch. Unfortunately he parks his truck in the light of the sun; this triggers a temperature alarm, informing the driver to move the truck. However, quite soon a new alarm is activated, now the water is empty, the animals consumed more water than expected this warm day. It is easily fixed and he continues the journey to Motala.

When the animals arrive to Motala, Johnson gets a log file with more details about the transport and the animals' condition. Johnson is very satisfied with the delivery.

Happy Animals receives a similar log plus some additional information about fuel consumption, work hours, driving times, speed, service threshold level parameters and other

useful data. Some of this information can be used to assure authorities and customers that regulations have been followed and that the animals are handled with respect and care. Other data can be used to optimize and predict transports better in the future. The improved transparency, security and delivery precision will increase the competitiveness of Happy Animals.

III. BACKGROUND

The rapid development of solutions and standards in wired and wireless communication, positioning, geographical information systems, ubiquitous embedded devices and mobile terminals makes it economically feasible to create integrated tracking services for goods on a global scale. Combined with state of the art software development and deployment technologies new services can be provided for multiple actors in a logistic or transport chain all the way from suppliers to destinations.

Fig. 1. T4D – New things must be evaluated in the real physical world

A. Related work

The Open Services Gateway Initiative (OSGi™) is an industrial initiative, started 1999. Reference [6] discusses OSGi as a gateway between a sensor network and client terminals. Overviews, benefits of the standard, development tools and typical use cases are presented in references [7], and [8]. In reference [9] an intelligent “futuristic” home is presented. The references [9] and [11], discuss how OSGi standard components and devices can be used to implement context aware functions. In [12] a concept called “smart spaces” is discussed using OSGi to build an environment that supports independent living for elderly. In [13] Mark Weiser’s vision known as ubiquitous computing is described. Deborah Estrin and her colleagues [14] describe the use of pervasive networking to acquire data from the physical environment. John A. Stankovic [15] describes different research problems related to real time communication in wireless sensor networks. The use of OSGi technology, wireless sensor nodes and PDAs related to T4 were prototyped and evaluated in a Master Thesis [16].

B. The OSGi Technology

OSGi supports handling of software as packages of related programs, called bundles. Some important services that are offered by the OSGi specification 2 are presented here:

- A *Package Admin Service* used to resolve dependencies between bundles exporting services and bundles using them.
- A *Permission Admin Service* can be used to define what files a bundle can use and how.
- Bundles can use the *Log Service* to store and retrieve messages of debug, warning and error type.
- An *HTTP Service* enables to send and retrieve information to and from a service gateway using a web browser.
- A *Device Access Specification* describes how devices are detected and how device drivers are registered.
- To handle a device remotely in a secure way, a *User Administration Service* can be used to identify and decide who is permitted to perform remote control actions and not.
- At deployment an application specific configuration can be set up using the *Configuration Management Services*.
- Using *Preferences Management Services* bundles can be given the ability to store data persistently before stopping and acquire it again when running.

C. Fleet Management Systems

Systems based on bar code or passive RFID identification and use of GPS for tracking and surveillance of goods of different kinds have been implemented and used by large delivery companies such as UPS and DHL. There are also transport information systems, such as DynaFleet from Volvo, for monitoring and management of vehicle fleets.

IV. THE T4 TRACKING AND SURVEILLANCE SYSTEM

The T4 system proposed in this paper differs from fleet management systems in that it uses a network of intelligent Active-RFID tags [17] or motes [18] equipped with sensors, see Fig. 2 for tracking and measurement of individual cargo items and characteristics, i.e. not only the vehicle.

Fig. 2. Active-RFID sensor node (tag) without enclosure

T4 is made flexible and adaptable by the use of standard components with open standardized interfaces and new methodology for distribution of new or upgraded services. The software is built as a composition of components that can cooperate and be configured to specific environmental needs. T4 also includes unique services that make it possible to support, synchronize and coordinate the cooperation between several small fleets.

The T4 architecture is designed to make it easy to integrate related existing applications and services. This simplifies the replacement and use of other kinds of sensors and supports connections to and integration with other systems. This means that systems tailored for different customers and markets can be developed with small additional cost. The architecture is thus not locked to fleet management and goods surveillance, but suit similar needs within other areas.

A. System Description

The system contains 1) service provider nodes; 2) service gateways; 3) mobile access points; 4) sensor nodes based on active RFID (or motes), and 5) client terminals. A logical reference model of the system is described in Fig. 3.

Fig. 3. T4 system reference model

The connection between the mobile access point and the data- and telecommunications infrastructure is in T4D based on GSM/GPRS but could be any kind of 2-3G cellular wireless data communication technique with good national and international coverage e.g. MOBITEX or satellite systems such as Inmarsat or Iridium.

The wireless sensor network is based on Active-RFID (or mote) RF devices, using the internationally open 868 MHz, 915 MHz and 2.4 GHz ISM bands, and can be equipped with many different types of sensors.

1) Service Provider Nodes

The service providers are nodes (servers and databases) that deliver services and service bundles to gateways, mobile access points and client terminals. New functionality can be obtained by downloading from the service providers.

2) Service Gateways

A service gateway is a central component in the architecture. It is used to connect an internal network and its components to an external network and its components. For example, it can be used to connect service providers and clients to devices in the local wireless sensor networks.

3) Mobile Access Points

The mobile access point is a central component in each vehicle. Mobile access points act as service gateways in that they connect a wireless sensor network and its components to an infrastructure network (e.g. via GSM/GPRS). A service provider or an operator maintains both access point hardware and gateways and the service bundles that are executed on these. The management of the services includes: downloading, updating, starting, stopping and removing them.

4) Active RFID Sensor Nodes (Motes)

Wireless Active-RFID sensor nodes are the units that measure, monitor and collect data about the goods and transporting vehicles. These nodes can be scheduled to wake up at regular intervals or be waked up (triggered) directly by the sensors if a measured value passes a defined threshold level.

5) Client Terminals

Client terminals are used to communicate with services provided by service providers and thus indirectly with the devices in the sensor networks via the service gateway and mobile access points, for example to get the temperature from a thermometer in a local sensor network.

Fig. 4. Vehicle with Mobile Access Point and Active-RFID sensors

B. Actor Perspectives on T4

Here we describe how the system can be seen from the use perspective of different actors.

1) Transport customers

A customer (in the supply or receiving end of the chain) that orders transport of some goods can get statistics about the transport company itself regarding its handling of goods, time points, predictability etc. Much of the handling can be made via a web interface. The customer can select transport supplier, the desired kind of transport service and then also ask to get a report on how the selected service was carried out, for audit purposes.

2) Receivers of goods

The receiver can, by the help of a web-browser interface, follow the goods during its transport and get regular updates on where the goods are and when it is expected to arrive. It is also possible to get a log of where the goods have been and how it has been handled. For example, a temperature log or a log of time points when the items have been exposed to higher acceleration forces than a predefined limit.

3) Transport companies

A transport company can monitor all vehicles in its fleet and their load in real time. Administration of dispatch orders can be handled in electronic computerized form to minimize work. Alarm functions can be triggered when exceptions occur, such as if a vehicle leaves the planned route or uses higher speed or more fuel than wanted. Drivers' work hours, driving style etc. can be saved in a log.

4) Drivers

Drivers can see all their cargo and selected parts of administrative information, for example destination address. The driver can be guided to the destination address and also see its physical position in a map. The goods is connected to the receivers address and if the driver happens to offload the goods at the wrong address a notification alarm can be sent to the driver and the transport company so that the mistake can be recognized and corrected.

5) Vehicle

Each vehicle is connected to the Internet via a wireless access point, enabling to relay information about its own identity and position as well as give access to parameters related to the transported goods, driver and vehicle data.

6) Goods

Each unit of goods has its own identity and optionally sensors for temperature, moisture and acceleration which can be tracked and logged during the transport. The Active-RFID tags communicate with the access point in the vehicle (and other places) at: departure, reloading and destination points and on board trains or ships.

7) Service Providers

There can be one or more provider of telematic and logistic services. Each provider can use the technology of the presented T4 concept to create national or international information services based also on the use of other data- and telecommunications related infrastructure services. These service providers support both transport and end customer companies that use the transport services.

C. Service Perspectives on T4

The proposed T4 services provide real-time, in-transit visibility and traceability throughout the entire supply chain – to support delivery in time, at the right place, with predictability and traceability. Both carrier and goods owners will have a transparent transport chain with full control of the goods in transit. The driver is helped by simplified drive orders, delivery receipts, navigation and additional safety and security.

Typical questions of the goods owner are e.g.: Where are my parcels? Are they on the right track? Will they be there on time? Is somebody stealing it? Is there a weak link in my chain? Where was a mistake made? Can I optimize something? What is the status of my assets? Are my assets handled correctly? Are they tampered with? What is the environment around my asset? Is it cold/warm, dropped/crushed, soaked/dried?

1) *Quality Assurance*

T4 supports just-in-time delivery in the transport chain and increased delivery predictability. Faults can be pinpointed to time and place in order to determine responsibility and assign corrective actions. This also means that correct handling of a product can be verified throughout the supply chain. Goods without damage will be sent to the right address and with a handling certificate.

2) *Decreased Costs*

A tracking system such as T4 can detect and identify damaged cargo early or apply corrective action before damage occurs, as well as manage slightly damaged cargo. T4 can locate time losses for example at the loading dock and instantly determine the condition of the cargo at delivery. The solution enables decisions in real time, for example if the goods, parcel, or pallets experience an alarm event, the manager can take action based on live data.

3) *Traceability Supply Chain Awareness*

History for the cargo and for each parcel is stored in logs. This enables analysis for improvement of the delivery chain and taking of records for regulatory compliance. A transparent supply chain increases the awareness and makes improvements possible for all involved parties.

4) *Integration with other Systems*

The system is able to work stand-alone integrated with other existing systems through industry standard interfaces. It is also easily adapted to customer processes.

D. *Research Issues*

To secure information about the supply chain the goods must be monitored and the measured data reliably stored for analysis both in real time and as a post processing task. Data may need to be replicated at different levels to reduce the risk of data loss. By use of different forms of data fusion, interpolation, refinement and data mining, important analysis and decision material can be created, estimated, restored or compensated for.

It must be investigated if the wireless sensor nodes can use IEEE 802.15.4 and the Zigbee protocol standards and if it is energy efficient to adopt the IEEE 1451 smart transducer interface or if acquired sensor values better be translated and calibrated by the central server node.

The mobile sensor network can be provided as a service by an operator that is independent in relation to transport and logistics companies as well as to suppliers and end customers involved in the overall business chain. The sensor network consists of several parts. The most important are measuring

sensors, communication devices, application servers and user terminals.

In order to achieve wide area coverage the communication devices are attached as mobile access points and gateways between the sensor network and public communication infrastructure (fixed and mobile telephony networks as well as data networks, such as the Internet). For total, global coverage, satellite communication can also be used. Application servers have an important role in the gathering and refinement of sensor data and to provide higher level services based on the information acquired from the sensor network.

The network as a whole is heterogeneous, using several radio based links of different types and with large difference in bandwidth between low energy, battery supplied, sensors in one end and optically connected high bandwidth servers in the other. To increase coverage and reduce energy consumption wake-up and different types of ad hoc, scatter- and multi hop networking and routing techniques, such as those presented in [19] and [20] need to be evaluated.

Novel techniques for buffering and replication of data are also needed to safeguard the information in case of temporary lack of coverage or other types of radio disturbances. The system solution must also be scalable.

Some of these problems can be solved with current available technology; other challenges and discoveries will require research work to be done – this is one important reason to run and pursue the demonstrator project T4D.

E. *Experiences and Results*

Mobile, wirelessly connected, sensor networks have many applications. Ideas and solutions used in the T4 architecture can be used in other areas and for other purposes, for example to support care of disabled people wanting to live at home and in similar surveillance/monitoring applications.

In this paper the main purpose has been to present how to monitor individual cargo items in supply chains, in terms of their state and interesting state changes (events). There are sometimes many interrelated events and chains of events occurring concurrently in a complex logistics scenario that need to be traced and coordinated.

An important side effect is that the information gathered can also provide information to other vehicles, for example about the current or predictable traffic situation, to avoid queues or find the fastest route etc. In a sense each vehicle carries a valuable mobile sensor network asset that can be combined with other on-board systems.

So far most of the experiences have been achieved by prototyping, master thesis works and actual product development. Free2move has provided knowledge related to their wireless Active-RFID sensor nodes (tags) and access points (readers) as well as Bluetooth links. Their sensor node is based on a Nordic VLSI nRF2401 single chip transceiver operating in the 2.4 GHz ISM band and is equipped with a very low power microcontroller, Microchip PIC16F87, executing communication protocols and sensor functionality.

XCube Communication has contributed with results related to the demonstrator and has evaluated the use of OSGi technology and Active-RFID tags. They are also developing a commercial product, called SEAL™ similar to T4 from an architecture and technology point of view. This system is today working on the ground. Based on active work within the regulatory groups in the aviation industry and the consumer electronics association their system is planned to support land-air-sea-freight systems, Fig. 5.

Fig. 5. System for transparent tracking of goods on a global scale

Both companies have gained experiences from their customers and in this way been involved in the knowledge building process together with researchers from Halmstad University. The T4 demonstrator is intended to help to identify important research issues for all parties.

The research on T4 is an ongoing project. There are many areas that can be identified and further investigated and more research is needed both on a functional level and on a non-functional level to improve or optimize different identified sub-problem areas. For example, the design of small, ultra-low power cost efficient Active-RFID tags. Another research issue is the suitability of protocols for energy efficient and reliable delivery of event oriented messages. A third is optimization of the architecture including design and implementation of remotely upgradeable, reliable and scalable software components and system configurations further supporting and enhancing the service provisioning facilities and the system characteristics of T4.

V. CONCLUSION

The T4 architecture enables flexible, scalable systems and real-time tracking using smart sensor networks. The T4 services enable quality assurance, detection of weak links, cost saving through early detection, optimization, instant quality check before unloading, and branding benefits through improved quality of transports. This in combination with support for secure data handling, life-cycle-management and ease of integration enables tracking services “from anywhere to anywhere”.

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