SENSEI traffic modelling

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***Abstract* — SENSEI project is an Integrated Project in the EU's Seventh Framework Programme, in the ICT (Information and Communication Technologies) programme. The aim of the research done in SENSEI project is Integrating the Physical with the Digital World of the Network of the Future. In this paper we present SENSEI traffic model developed for analysis and simulations, which will be performed during the project in order to investigate impact of SENSEI generated traffic on mobile networks. A new traffic model is needed having in mind that the behaviour of wireless sensor and actuator networks and M2M communication in terms of generated traffic is completely different than the traffic generated by standard mobile network subscribers today.**

***Key words* — Internet of things, FP7 SENSEI, traffic model, wireless sensor networks, actuator networks, M2M communication.**

I. INTRODUCTION

SENSEI (Integrating the Physical with the Digital World of the Network of the Future) is an Integrated Project in the EU's Seventh Framework Programme [1], in the ICT (Information and Communication Technologies) programme. In order to realise the vision of Ambient Intelligence in a future network and service environment, heterogeneous wireless sensor and actuator networks (WS&AN) have to be integrated into a common framework of global scale and made available to services and applications via universal service interfaces. SENSEI creates an open, business driven architecture that fundamentally addresses the scalability problems for a large number of globally distributed WS&AN devices. It provides necessary network and information management services to enable reliable and accurate context information retrieval and interaction with the physical environment. By adding mechanisms for accounting, security, privacy and trust it enables an open and secure market space for context-awareness and real world interaction.

The SENSEI will rely on the connectivity substrate provided by future networks in order to realize the various interactions between SENSEI resources, resource users, and other system components. While the deployment of resources and system components will be initially incremental, it is expected to rapidly grow in scale, dwarfing the number of current end hosts on the Internet by orders of magnitude. The type of traffic generated by the interactions with these resources and load requirements may differ from existing traffic patterns for which current networks have been dimensioned. It is therefore essential to gain an understanding of how the traffic generated by the SENSEI system will impact the performance of the underlying future networks.

Thinking about future, we believe that mobile networks (GSM/GPRS/EDGE/WCDMA/HSPA/LTE) will play very important role in Future Internet. On the other hand, they are very suitable for SENSEI resources, having in mind mobility they are offering and the fact that whole necessary infrastructure is already there, for majority of locations. Mobile networks today have approximately 4 billion of subscribers, which is close to penetration of 100%. On the other hand there are billions and billions of things that can be connected in future, which makes this area very interesting for future mobile networks growth.

Today mobile networks are dimensioned according to standard traffic models, which are based on typical subscriber behaviour, which is expressed in typical time spent using speech service, number of send/received messages (SMS, MMS) and data downloaded. For Internet of Things traffic modelling, and in this particular case SENSEI traffic modelling, it is obvious that we need completely new traffic models. In this paper we present the approach to model (or dimension) the SENSEI traffic, carried-out for purposes of SENSEI project research.

II. SENSEI SCENARIOS – INPUT FOR SENSEI TRAFFIC MODEL

SENSEI project has defined eighteen representative scenarios [2]. The scenarios are presenting applications in the area of transport (*Multimodal traveller, Robot taxis or Sustainable transport),* enterprise (*Smart factory, Working in a plant, Tracking in Supply Chain, etc.*), and smart spaces (*Smart places, Networked inhabitants, Intelligent home, Facility management, etc.*). Although a lot of effort has been done in these scenario definitions in order to cover as many as possible types of applications, it is clear that every possible case can not be covered. On the other hand, each scenario has many aspects of application and lot of scenes where interactions between different entities exchanging messages exist. We have selected multimodal traveller scenario as the most representative one, performed detailed analysis of that scenario, and generated corresponding traffic model. Other applications will be modelled by multiplying the traffic generated by the

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selected scenario using appropriate multiplication factor.

The Multimodal traveller scenario has been chosen as the basic scenario because it utilizes mobile network extensively. SENSEI users who participate in Multimodal traveller scenario are mobile across a wide area and hence the additional traffic can not be served by simply installing/upgrading hotspot base stations.

In Multimodal traveller scenario [2] five different scenes have been defined:

Web Based Application CAR POOL: *A driver and two passengers are travelling from a suburb to their workplaces in different parts of the city. They met up in the morning using a web based service that enables citizens to use proactive car-pooling, depending on their real-time situation and agenda. Each morning the system informs them on whether they will need to take their own car, with whom they will be travelling, and where they will need to pick up and drop off passengers in order to optimize connections with other transport means*.

Web Based journey Planner: *The web-based journey planner receives live information from the road authority on the state of the roads including traffic jams, accidents and various weather conditions such as snowfall, humidity, precipitation. The car also transmits information to the road authority regarding speed, distance travelled, use of windscreen wipers to estimate precipitation, etc. Throughout the group's journey, this information is continuously updated.*

Passenger Drop Off: *As he passes a bus stop, the driver is alerted by the dashboard that he must drop off a passenger to let him or her continue their travel using the multimodal public transport system.*

Public Transport Passenger Behaviour Sensor Network: *Sensors track the travellers use of stops and provide real-time data on customer levels across the network. This allows the buses, trams, trains, ferries, taxis and bicycles to respond to the city's needs on the fly, and timetables have become a thing of the past as public transport effectively reacts to the patterns of the city. All nodes in this network are connected with each other and share their data. Travellers can 'hail' a bus or tram in the same way they do a taxi - by indicating with their mobile that they want to get on, or that they will at a particular point/location, or by walking to the stop where the sensors are able to read the presence of a customer. After a time, patterns of use emerge that predict usage, meaning the users rarely have to actively 'hail' anything.*

Public Transport Ticket Service: *Ticketing is provided through mobile terminals based on NFC capabilities or sensors placed around that automatically register the access and exit points. People gain 'carbon credits' by using public transport regularly and the credit is carried over into their overall 'sustainability index'.*

In our investigation, we will focus on traffic destined for transfer over mobile networks.

III. TRAFFIC MODEL

In a future internetworking architecture for WS&ANs, like SENSEI architecture, we can categorise the traffic of interest into two types. The first type is application traffic, i.e. traffic generated by new applications supported by SENSEI, for example Web Based CAR POOL or Web Based Journey Planner. The Second type is traffic generated by interactions in SENSEI resource layer, which is communication needed to support SENSEI applications [3].

A. Application traffic

The first step in application traffic analysis is to analyse scene by scene, where we will be observing one car with a driver and two passengers (according to the scenario). Initially, we will model traffic generated per car. Later on, we will discuss penetration of this application, i.e. how many subscribers/cars will participate in the SENSEI Multimodal traveller scenario.

Web Based Application CAR POOL scene analysis is shown in Figure 1. All messages that are being exchanged are presented, with approximates size of each message (in kilobytes). The arrows indicate the direction of each message, i.e. if they are sent on uplink (from the user to base station) or on downlink (from base station to the user).

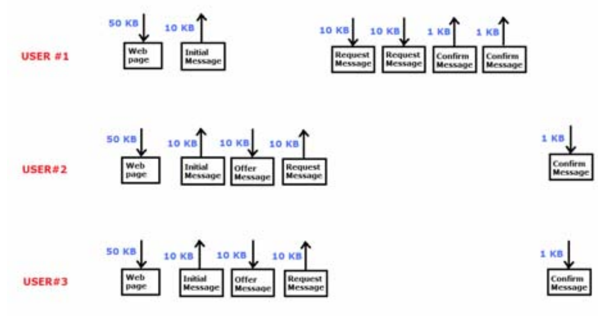

Figure 1 Web Based Application CAR POOL scene analysis

In the Web Based journey Planner scene, information used by the application from the road authority is continuously updated. Hence, the traffic is modelled using the frequency of the messages (60 messages per hour) and the message sizes of 2KB. These messages are sent on downlink. It is important to emphasize that this traffic is generated per vehicle, not per subscriber. Information provided from car to the road authority is analysed as SENSEI resource layer traffic.

Messages exchanged in the Passenger Drop Off scene with the corresponding values for the frequency, size and direction (uplink/downlink) are outlined in Figure 2.

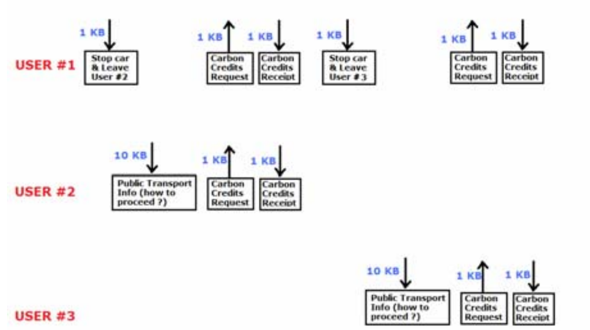

Figure 2 Passenger Drop Off scene analysis

B. *SENSEI resource layer traffic*

Before we proceed with the SENSEI resource layer traffic, we will give a short overview of the SENSEI architecture [3]. The most important entities in the SENSEI architecture are (Figure 3):

- ***Resource Users***, typically applications that require real world information
- ***Resources***, typically sensors or other sources of information, can be single or composite
- ***Resource Provider (REP)*** hosts one or more Resources and provides uniform access to those via the Resource Access Function (RAF). Resource Users interact with the Resources via the Resource Access Interface (RAI).
- ***Resource Directory***, implements the Resource Discovery function. In order to be discoverable by other Resource Users in the SENSEI Resource Layer, a Resource must be registered with the Resource Directory. Using the Resource Publication Interface (RPI), a Resource Provider registers one or more Resources with the Resource Publication Function (RPF). Using the Resource Lookup Interface (RLI), Resource Users can interact with the Resource Lookup Function (RLF) to discover Resources of interest in the SENSEI Resource Layer.
- ***Semantic Query Resolver***, in charge of query analysis and dynamic resource creation, if necessary.
- ***Execution manager***, processes requests for real world context and actuation tasks.

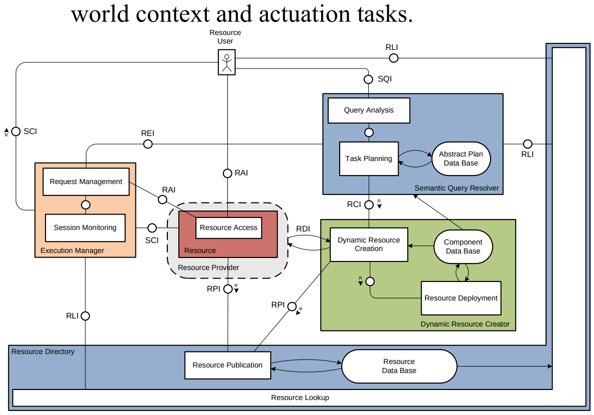

Figure 3 SENSEI resource layer architecture

For purposes of analysis of scene Web Based Journey Planner we will assume:

- Resource User – Road Authority
- REP – Car gateway, with sensors providing information about: speed, position, weather conditions, etc.
- Journey planner receives information from road authorities as application traffic (i.e. not using SENSEI protocols). The Road Authorities maintain advanced application, which delivers information about the state of the roads based on the data provided by the SENSEI system (gathered from different REPs like car gateways).

Hence the SENSEI level activities (at the resource layer) are:

- REP registers with the RD at the beginning of journey.
- REP periodically updates Resource Directory (with period Texp).
- Resource user continuously requests data from the REPs (periodically, with period Treq) via RAI

Figure 4 shows the corresponding SENSEI resource layer interactions for this scene.

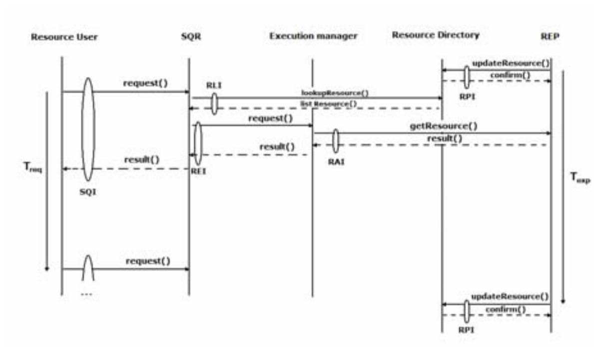

Figure 4 SENSEI resource layer interactions - Web Based Journey Planner Scene

From a mobile network prospective, RPI interface is of interest, since it is going to be the most probably realized through a mobile network radio interface. We will focus on messages going via RPI, and model them using the following parameters: Texp=1min, *publish* and *update* message sizes 10KB (uplink messages), and *confirm* message size 1KB (downlink message).

A similar work has been done with the Public Transport Passenger Behaviour Sensor Network scene. We have made the following assumption in the analysis:

- Resource User – Public Transportation Authority
- REP – Smart station gateway
- Smart station system communicates with travellers their presence, bus/tram that they are waiting for, time they have spent waiting.

Hence the SENSEI level activities (at the resource layer) are:

- REP registers with the RD
- REP updates Resource Directory whenever the first person waiting for a bus on a certain line comes to a station. Resource directory is updated with a tag dedicated to that bus number (i.e. the bus stop informs the RD that it has interest in line XYZ).
- Resource user subscribes (lookup subscription) to all bus stops to get informed about any changes in the list of bus lines with passengers waiting
- Resource user uses RAI to access the REPs and retrieves required information (for example number of people waiting for specific bus, average waiting time, etc.)

The following figure (Fig.5) shows the corresponding SENSEI resource layer interactions for this scene.

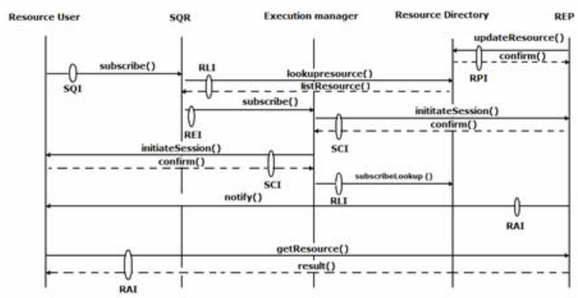

Figure 5 SENSEI resource layer interactions - Public Transport Passenger Behaviour Sensor Network Scene

From mobile network prospective, we are interested in messages exchanged on RPI and RAI interfaces. Total amount of traffic can be estimated as N x (*updateResource, confirm)* messages, where N is number of performed journeys with public transportation and 60 x (*getResource, result*) messages per hour per public transport station (assuming that system checks station status each minute). We will assume size of *updateResource* and the *result* message of 10KB (uplink messages), and size of *confirm* and *getResource* message *of 1KB* (downlink messages).

C. SENSEI user penetration

When it comes to user penetration, we will refer to documents [6] and [7], study of transport in the city of London (UK). According the study, number of travellers in peak hour (8 AM) in London is 1.8 million, where 875 000 of travellers is travelling by car, while 925 000 is using public transportation. We will use assumption from [5] that SENSEI penetration is 2/3 (1.2 million SENSEI travellers, 583 000 of them uses car, while 617 000 uses public transportation). We need to estimate number of SENSEI cars, as we saw that some amount of traffic is generated per vehicle, not per traveller. We will assume that ratio of SENSEI cars and SENSEI car travellers is 1:2, or in other words we will assume that number of SENSEI cars is ½ of number of SENSEI car travellers (292 000 cars). According [6] and [7], number of public transport stations sensors is 15050. Now, we will scale all the numbers to London population of 7.5 million. Penetration figures are presented in table 1.

TABLE 1: SENSEI PENETRATION

SENSEI SUBSCRIBER	***Penetration (out of total population [%])***
SENSEI CAR TRAVELLER	7.7
SENSEI PUBLIC TRANSPORT TRAVELLER	8.2
SENSEI CARS	3.9
SENSEI PUBLIC TRANSPORT STATION SENSORS	0.2

IV. CONCLUSION

What can be expected in future is Internet of things, where not just everybody, but rather everybody and everything will be connected. With Internet of things, users of mobile network will not be just people, but different machines and devices, and generally things which are present in mobile network today as well, but their presence is not so significant yet. These “New mobile network users” will have quite different behaviour, from prospective of traffic they generate, comparing regular mobile network subscribers. Since behaviour is different, new traffic models must be defined. In this paper we have presented SENSEI traffic model, which is developed for SENSEI project research purposes, and it is based on SENSEI defined scenarios. We intend to use this model as input for future work, where we will investigate different aspects of impact of SENSEI users and traffic on mobile networks.

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ABSTRAKT

SENSEI projekat je deo FP7 projekta koje finansira EU u okviru ICT programa. Tema istraživanja u okviru SENSEI projekta je integrisanje stvarnog sveta sa digitalnim svetom mreža budućnosti. U ovom radu će biti predstavljen model saobraćaja, koji je razvijen za potrebe analize uticaja SENSEI-a na mobilne mreže i poslužiće kao ulazni podatak za dalje istraživanje i simulacije. Imajući u vidu da je ponašanje bežičnih senzorskih i aktuatorskih mreža i M2M komunikacije potpuno drugačije u poređenju sa ponašanjem mobilnih korisnika, novi saobraćajni model je bio neophodan.

MODELOVANJE SENSEI SAOBRAĆAJA

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