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SENSEI traffic impact on mobile wireless networks

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Abstract. With an increasing number of connected devices and the coming wave of Internet of Things services, it is important to understand how the modern communication networks will cope with the additional traffic load. In this paper, an analysis of several Internet of things scenarios as envisioned by the FP7 SENSEI project have been performed to understand how the traffic is being generated in each of the scenarios. Based on the analysis, a traffic model is derived and then used to assess its impact on wireless mobile networks from the networks' dimensioning point of view. The results of this analysis are then presented.

Keywords: Internet of things, Future Internet, traffic modeling, M2M

Introduction

FP7 SENSEI project focuses on integration of heterogeneous wireless sensor and actuator networks (WS&AN) into a common framework of global scale [1]. It relies on the connectivity substrate provided by future networks to realize the various interactions between SENSEI resources (sensors, actuators and in general Internet of Things devices), resource users, and other components [3].

Today, there are more than 4 billion mobile subscribers. While the deployment of connected Internet of Things (IoT) devices and services will be initially incremental, it is expected that it will rapidly grow in scale, dwarfing the number of current end hosts on the Internet by orders of magnitude. The type and amount of traffic generated by the interactions with these devices may differ from the existing traffic patterns for which the current networks (in particular modern mobile networks WCDMA and LTE) have been dimensioned. Currently, mobile networks are dimensioned using standard traffic models, which are based on a typical subscriber behavior expressed in typical time spent using speech service, number of sent/received messages (SMS, MMS) and the amount of data subscriber is downloading. These traffic models do not take into account traffic generated by smart devices. It is therefore essential to understand how these smart devices will generate the network traffic and to take that traffic into account when designing and optimizing current and future communication networks, including Future Internet.

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In this paper we present an approach to model the Internet of Things traffic based on a set of representative scenarios together with the initial results of dimensioning a representative mobile network using a new traffic model that combines the standard traffic mix with the traffic generated by smart devices participating in selected IoT scenario.

1. IoT Scenarios – Input for Traffic Model Definition

Internet of Things scenarios and applications are wide and diverse, with a variety of user interactions, message sequences, requirements and QoS expectations. The SENSEI project has defined 18 different IoT scenarios [2] that span across several application domains. In order to build a representative IoT traffic model the foreseen scenarios were analyzed to identify how the information is being generated and exchanged in each of the scenarios (who generates what information, how often it is transferred and over what type of the network, what is the message size and frequency, etc.). As the focus of our research was on analysis of traffic impact on mobile access networks, we focused on scenarios that primarily utilize mobile networks for information transfer. After identifying the interactions between different entities in the system for each of the scenarios and determining the frequency of message exchanges, the size of each message and the quality of service (QoS) requirements for each scenario, the *Multimodal traveler* scenario [2] has been selected as the representative IoT scenario for assessing the impact of IoT traffic on mobile networks.

This scenario was selected for several reasons. It generates the highest and most demanding traffic load on the mobile networks. Actors in the scenario are mobile across a wide area and are thus generating traffic in different parts of a network therefore influencing a number of the network nodes. This is important as the analysis of the impact of the additional traffic on mobile networks can be more sophisticated when the traffic growth is spread across the network. The scenarios that take place in a limited area like the *Smart factory* or *Smart places* scenarios [2] can be taken care of by simple installation/upgrade of hotspot base stations and as such are not of interest.

In order to take into account the impact of traffic generated in other scenarios and potential increase of the IoT services and devices over time, we introduced a multiplication factor *k.* By increasing this factor, we were able to simulate an increased traffic load generated by other scenarios and or new users. The following section analyzes the selected scenario in detail.

1.1. Multimodal traveler scenario analysis

Five different scenes have been defined for this scenario: Web Based Car Pool, Web Based Journey Planner, Passenger Drop Off, Public Transport Passenger Behaviour Sensor Network and the Public Transport Ticket Service scene. The last scene was excluded from the analysis as practically no traffic over mobile networks is generated in the scene.

All messages transferred through the system are classified into one of the following two groups:

- Application traffic, generated by new applications, for example Web Based Car Pool or Web Based Journey Planner;
- System traffic, generated by interactions in the SENSEI resource layer [3].

Consequently, possible message sequences were identified and classified according to the traffic types defined above for each identified scene. For the identified messages, the message sizes and the frequency of message exchanges (where applicable) were defined. Based on that, an estimation of the traffic generated by an active user was made. In the following subsections, each of the scenes is first described and analysed from the application and system traffic perspectives.

1.1.1. Web Based Car Pool Scene Analysis

Story: *Web Based Car Pool application enables citizens to use proactive car-pooling, depending on their real-time situation and agenda.*

Application traffic analysis

This scene consists of the following application traffic related activities:

- Assume user #1 is a driver and users #2 and #3 are the passengers. At the beginning, all three users download the Car pool service web page.
- In the initial message, users provide information about the starting points of their journeys, destinations etc.
- The *Car pool* service sends the *"car pool offer"* messages to users #2 and #3 informing them about the proposed journey (pick up places and times, the route, etc). If they agree with the proposal they reply with request messages asking for a place in the car.
- The *Car pool* service sends a request message to user #1. After user #1 sends a confirm message, where he accepts the proposed route, a confirmation message is sent to users #2 and #3.

The message exchanges for this scene are shown in **Figure 1**, with the direction (uplink/downlink) and estimated size of each message. Based on this we can define the total amount of the application traffic for all three users: 192 KB on downlink and 34 KB on uplink which gives 64 KB/BH (busy hour) on downlink and 12 KB/BH on uplink per single active user.

1.1.2. Web Based Journey Planner Scene Analysis

Story: *Web-Based Journey Planner application located in a car receives live information from the road authority on the state of the roads (including traffic jams, accidents and various weather conditions), while at the same time transmits information to the road authority collected from different sensors built in a car (speed, distance, use of windscreen wipers…).*

Application traffic analysis

Information received by the journey planner application from the road authorities about state of the roads is considered to be application traffic (i.e. not using SENSEI protocols). It will be modelled with 120 messages per hour, where size of each message is estimated to be 1 KB.

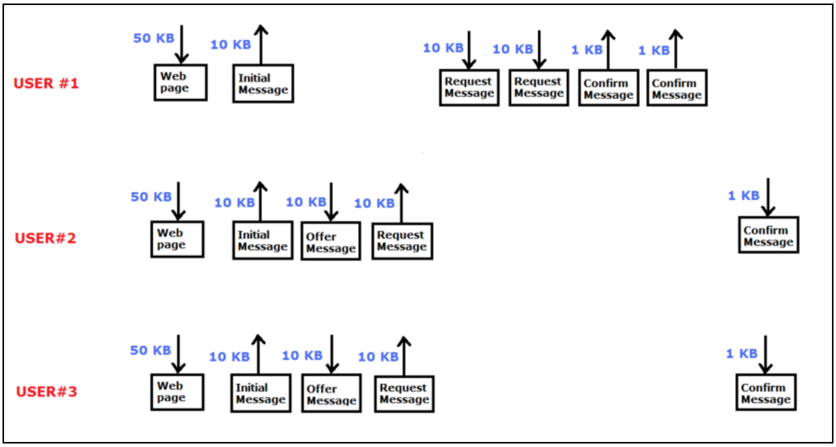

Figure 1 Web Based Car Pool Scene – Application traffic

SENSEI resource layer traffic analysis

For the purpose of this analysis we assume:

- The Road Authority is a resource user;
- Car gateways connecting sensors built into the cars and providing information about the speed, position, weather conditions, etc. are acting as the REPs (Resource End Point);

Based on this, the following system level activities at the resource layer can be identified:

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

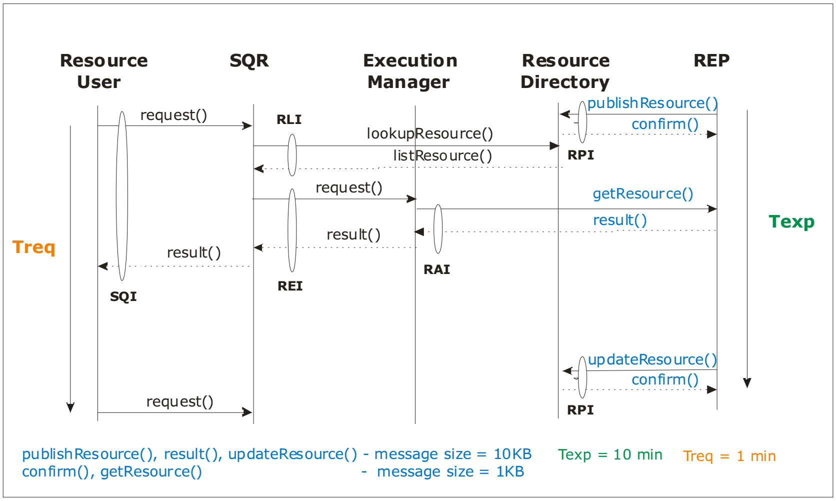

Figure 2 Web Based Journey Planner Scene – SENSEI system traffic

Figure 2 shows the corresponding SENSEI resource layer interactions for this scene. From the radio network interface perspective, messages of interest are considered to be the messages sent or received by a REP, either through RAI or RPI interface. Further, we assume Treq=1minute, Texp=10minutes, message size of 10KB for *publish(), updateResource()* and *result()* messages, and message size of 1 KB for *confirm()* and *getResource()* messages.

1.1.3. Passenger Drop Off Scene Analysis

Story: While passing by *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.*

Application traffic analysis

The activities related to the application traffic are the following:

- The car pool service informs User 1 to stop the car and drop off Users 2 and 3.
- The car pool service informs Users 2 and 3 to proceed with public transportation.
- All three users are awarded Carbon credits for using the car pool service.

Figure 3 shows the corresponding messages that are being exchanged including the direction (uplink/downlink) and an assumption of the size of each message .

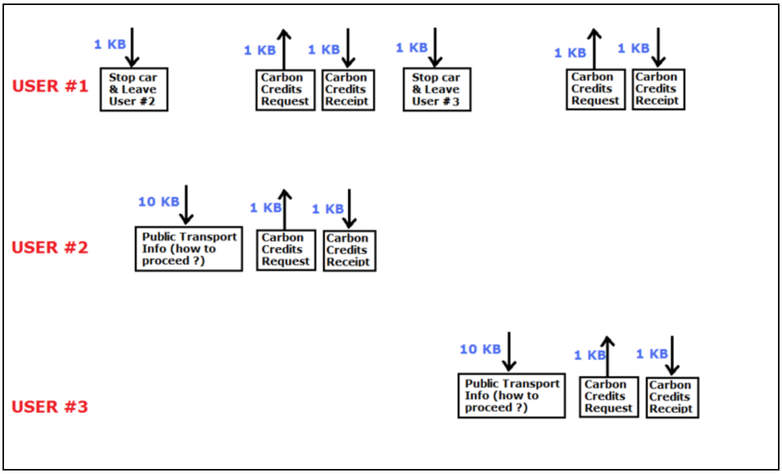

Figure 3 Passenger Drop Off Scene – Application traffic

1.1.4. Smart Public Transportation Stations Scene Analysis

Story: Public Transportation Stations are equipped with *sensors which track the travelers use of stops and provide real-time data on customer levels across the network..*

SENSEI resource layer traffic analysis

The activities at the resource layer are the following:

- REP updates the RD whenever the first person waiting for a bus on a certain line comes to a station. RD 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 users use the RAI to access the REPs and retrieve required information (i.e. number of people waiting for specific bus, average waiting time, etc.)

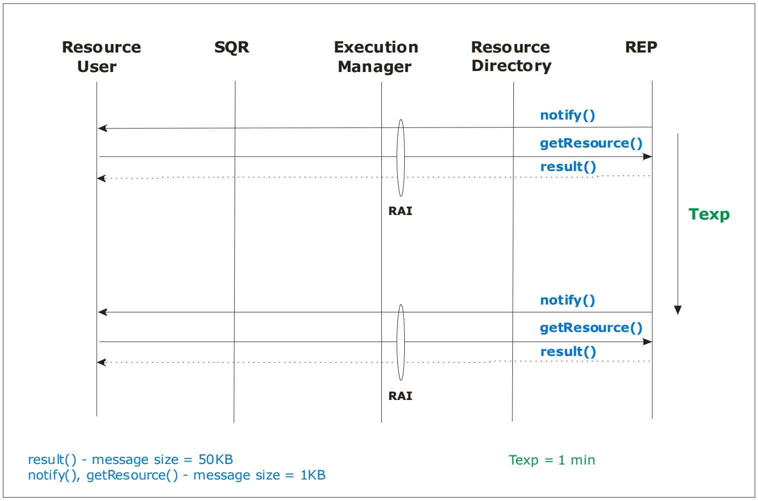

Figure 4 Smart Public Transportation Stations Scene – system traffic

Figure 4 shows the corresponding resource layer interactions for this scene. We assumed that on average, the public transportation system communicates with the Public Transportation Authority once per minute, where the *result()* message size is 50KB, while message size for the *notify()* and *getResource()* messages is 1KB.

2. Traffic Model

Based on the analysis presented in the previous section, it is now possible to specify the traffic generated by an active IoT user over a mobile network. In order to combine the IoT traffic with the standard mobile wireless network traffic (traffic generated by mobile users today: voice, data, SMS and MMS) and to build an aggregated traffic model, the IoT traffic has to be scaled and expressed in the same manner as the "standard" traffic, i.e. as the traffic generated per mobile subscriber during a busy hour.

The first step toward this modeling is the estimation of the number of potential active users at a given moment. In the selected scenario there are three types of users: (i) travelers, (ii) cars, and (iii) public transportation stations (devices). An estimation of the number of active users can be derived based on a study of transport for the city of London (UK) in [6] and [7]. According to the study, the total number of travelers during a peak hour in London is 1.8 million, of which 875000 are traveling by car and the remaining 925000 are using the public transport. Based on the assumption that penetration of the selected scenario is 2/3 [5], it is assumed that there are 1.2 million "IoT" travelers, of which 583000 are using cars, while 617000 use the public transport. Moreover, the number of "IoT" enabled cars has to be estimated, since a certain amount of traffic is generated per vehicle, not per traveler. We will assume that the ratio of the "IoT" enabled cars and the car travelers involved in the selected "IoT" scenario is 1:2, i.e. the number of the "IoT" enabled cars is two times smaller than the number of the "IoT" car travelers (292000 cars). The number of the public transport station sensors is considered to be 15050 according to [6] and [7].

Based on these estimates and knowing that there are 5 million mobile subscribers in London out of the total 7.5 million people, it is possible to scale the total number of the "IoT" users to match the London scale. Following the above assumptions and estimations, the traffic per mobile subscriber in the selected scenario can be computed. Table 1 summarizes the IoT traffic model.

Summary of the developed traffic model shows that one of the main differences of the IoT traffic mix in comparison to the existing traffic models is a more intensive traffic on uplink than on downlink. Although the calculations here are based on one selected scenario, this trend is noticeable in all analyzed IoT scenarios. Therefore, we believe that the traffic model presented in Table 1, reflects well the patterns of the IoT communication activities. This traffic model can be varied by controlling the multiplication factor *k,* to simulate higher penetration of IoT users.

Table 1 SENSEI MMT based traffic model summary

Scene	**Traffic Type**	**Traffic per Active user** [KB/BH]		**Penetration** (ratio between active users and number of mobile subscribers)	**Traffic per mobile subscriber** [KB/BH]	
		Uplink	Downlink		Uplink	Downlink
Web Based Car pool	Application	12	64	24% (travelers)	3	15
Web Based Journey Planner	Application	0	120	5.9% (cars)	0	7
	Resource layer	660	66		39	4
Passenger Drop Off	Application	1	12	24% (travelers)	0	3
Smart Public Transportation Stations	Resource layer	3060	60	0.3% (stations)	9	0
				MMT based traffic model	51	31

3. Traffic Impact Analysis

The scope of the analysis is to dimension the size of a radio network required to carry the regular mobile network traffic with and without the IoT traffic, in order to compare the results and assess the impact of the IoT traffic on the mobile access networks in terms of the infrastructure requirements like the number of base stations and the corresponding hardware units. The analysis has been done using Ericsson's simulation tool for radio network proposals.

The regular mobile network traffic (consisting of voice, SMS, web browsing, etc.) was modelled with standard Ericsson's traffic model. Parameters described by this model are: speech and video call traffic (which is expressed in miliErlangs/BusyHour/subscriber units), data traffic (which is expressed in KiloBytes/BusyHour/subscriber units), and distribution of terminals according to the data transfer capabilities (WCDMA R99, HSDPA, HSPA, expressed in percentage of each terminal type). The IoT traffic is added to the Ericsson traffic mode. Other IoT scenarios and increased number of IoT users are taken into account by using different multiplication factors - k, (k = 1, 2.5, 5, 7.5, 10).

Dimensioning of the mobile network was done for an area of an average European city. According to the EUROSTAT Urban Audit research performed in 2003/2004 [8], which covered 371 city in EU countries, including Norway, Switzerland, Croatia and Turkey, an average European city has population of approximately 400000 citizens and covers 150 square kilometers. The number of mobile subscribers is estimated to 2/3 of population, or 266 000 citizens. Distribution of the urban/suburban area was considered to be 50/50. All results are expressed in relative units compared to the existing radio network (k=0, i.e. no IoT traffic, standard mobile traffic only). It can be expected that this trend will not change in different geographical areas. The following assumptions were used as input to the network dimensioning:

- 266 000 mobile subscribers, 75 square kilometres of urban area, 75 square kilometres of Suburban area.
- Traffic model: Ericsson traffic model + IoT traffic model.
- Three sectors Node Bs, with 20W amplifier per each sector, one 5 MHz channel available;
- Five HSDPA SF16 codes per cell, 16QAM modulation;
- Area coverage probability: Urban (95% for speech, video call and R99 packet data service; 90% for HSPA service), Suburban (90% for speech, video call, R99 packet data service, HSPA service with target throughput 1.5Mbps)
- Okumura-Hata radio propagation model (A=155.1 dB for Urban and A=147.9 dB for Rural);
- Other to own cell interference factor (F=Ioth/Iown): F=0.72 for downlink and F=0.73 for uplink. Downlink Orthogonality factor: A=0.64

4. Results

The main output of the analysis is the number of required sites (a site is a location where a base station is placed) and the hardware units required to be deployed in each base station. The amount of hardware units is expressed as the number of necessary channel elements. One channel element corresponds to a NodeB hardware and processing power needed to serve one speech call. Based on the number of sites and the number of channel elements, the overall cost (CAPEX) of a radio network can be calculated.

Estimation of the number of required radio sites, for different amount of the total IoT traffic modeled by the multiplication factor k, is presented in Table 2 and Figure 5. It can be seen that for the lower values of k ($k < 3$) introduction of the selected IoT service does not impact the number of radio sites significantly which means that the existing mobile infrastructure is sufficient to cope with the initial IoT traffic. With the increase of IoT users and services (k>3), the number of required radio sites grows and optimization of mobile network protocols might be required (i.e. capacity expansion by introducing additional 5Mhz channels) to limit their growth and minimize CAPEX.

Table 2 Number of required base station sites and cell range

	Multiplication factor					
	0	**1**	**2.5**	**5**	**7.5**	**10**
Number of BS sites, Urban	52	52	52	59	71	85
Number of BS sites, Rural	34	34	42	56	70	84
Number of BS sites, Total	86	86	94	115	141	169
Cell range , Urban [km]	0.86	0.86	0.86	0.81	0.74	0.67
Cell range, Suburban [km]	1.06	1.06	0.96	0.83	0.74	0.68

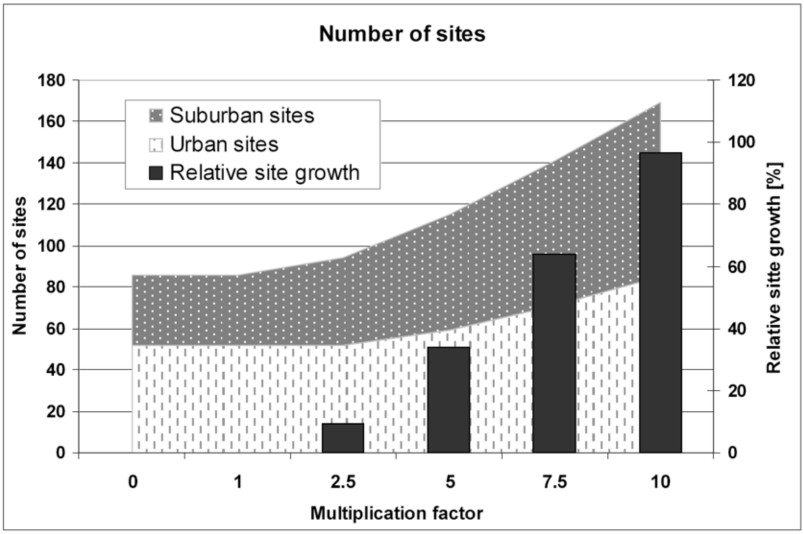

Figure 5 Number of required base station sites

The uplink hardware requirements as a function of the multiplication factor are given in Figure 6. These requirements have a steeper growth rate than the number of radio sites. In this case, a more significant increase of the uplink hardware requirements is visible already for k>1. Downlink hardware requirements also increase with the increase of the multiplication factor k, but at a lower rate, so the uplink hardware requirements are more sensitive on the IoT traffic growth.

5. Conclusion

Modeling of IoT traffic is a complex task as the IoT domain covers a wide and diverse range of applications, each with own specific way of working and characteristics. In this paper, we analyzed 18 different IoT scenarios spanning a number of application domains and created a traffic model that captures the main characteristic of the IoT services: demanding uplink traffic requirements. The level of IoT traffic was modeled using a multiplication traffic.

The estimation of the number of required base station sites showed that for intensive IoT traffic (k>5) a significant number of new sites is needed. Further, it is

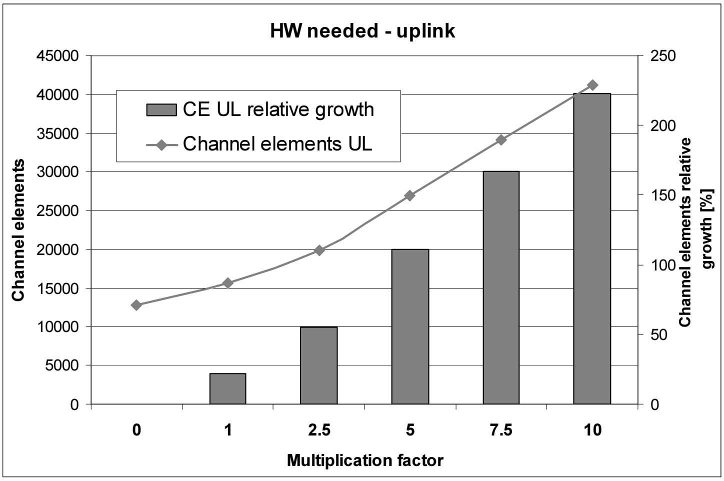

Figure 6 Hardware requirements

also observed is that the dimensioning of the uplink hardware elements is critical as its rate of increase is more rapid than in the case of the number of radio sites.

Further work will be focused on a more detailed analysis and simulation of traffic impact for a concrete network as well as performing similar analysis for LTE networks.

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