Technology and Business Aspects of M2M communications

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1. Introduction

The major vendors of telecom equipment and network operators envision that the traffic demand in next generation cellular networks will increase 1000 times by the year 2020. It is also expected that by this time the total number of diverse radio communicating devices will reach fifty billion.

The work in the SIG "Technology and Business aspects of M2M communications" resulted in identification of three main directions where WiNEMO Cost Action has a potential to contribute beyond the state-of-the-art:

1. Support for m2m communications in next generation cellular network;
2. Short-range reliable m2m communications;
3. Deployment and management aspects of m2m communications.

Amongst the considered use cases, in-vehicle and inter-vehicle scenarios predominate.

2. WiNEMO use cases for M2M communications

Looks like in-vehicle and intelligent transportation systems are pre-dominant uses cases for m2m communications in the WiNEMO community.

3. Support for M2M communications in wide-area wireless networks (UPF, TUT, LTU)

3.1. Channel Access Techniques

One of the key challenges to successfully deploy Machine-to-Machine (M2M) communications in Broadband Wireless Access Networks (BWAN), i.e., LTE and WIMAX, is to avoid congestion in the Radio Acces Network (RAN). The congestion in the RAN may be caused by a large number of M2M devices trying to simultaneously access the channel to ask for transmission resources [1].

User Equipment (UE) and M2M devices are allowed to transmit Bandwidth Requests (BR) in the Random Access Channel (RACH). A collision happens when several devices transmit BRs over the same resources at the same time. Besides the waste of network resources, collisions specially harm M2M devices as, in the one hand, the latency to successfully deliver the data message may be critical (i.e. an alarm) and, for the extra energy consumption that may be wasted in further retransmissions, on the other.

To mitigate the inefficiency of the RACH when a large number of nodes attempt to transmit in a short period of time, several solutions are provided [2]:

1. **Back-off based scheme:** The objective of this technique is to distribute the BRs sent by M2M devices over a large period of time (i.e. 1 second). The backoff for UEs is kept small.
2. **Access Class Barring (ACB) Based Scheme:** Similar to the use of a backoff. Devices are only allowed to transmit if a random computed variable (q) is smaller than a value (p) broadcast by the Base Station (BS). Otherwise, if p>q, the station is barred (it can not attempt a new transmission) for a certain time duration.
3. **Separating RACH Resources:** Separate RACH resources are assigned to M2M and UE devices. This technique mitigates the impact of M2M devices over UEs. However, M2M devices suffer from a high level of contention.
4. **Dynamic Allocation of RACH resources**: The RACH resources assigned to UEs and M2M devices are dynamically adjusted based on the instantaneous network state and requirements from both UEs and M2M devices.

From previous approaches, 3GPP seems to be in favor of ACB based schemes for LTE-advanced. In [3] two ACB-based methods for managing and sharing the RACH resources (preambles) between UE and M2M devices are proposed and evaluated. The first method completely splits the RACH resources in two disjoint sets, one for the UEs and the second for the M2M devices. Method 2 allows UE to use all the resources. In [4] an inter-BS cooperative ACB scheme is proposed. It is simply based on dynamically distribute the M2M devices over different Base Stations (BS) when M2M devices are under the coverage of several BS at the same time.

[1] A. Maeder, P. Rost, D. Staehle; "The Challenge of M2M Communications for the Cellular Radio Access Network". Joint ITG and Euro-NF Workshop "Visions of Future Generation Networks" (EuroView2011), 2011.

[2] S-Y. Lien, K-C. Chen; “Toward Ubiquituous Massive Accesses in 3GPP Machine-to-Machine Communications” IEEE Communications Magazine, April 2011.

[3] K.D. Lee, S. Kim, B. Yi; “Throughput Comparison of Random Access Methods for M2M

Service over LTE Networks”. IEEE GLOBECOM Workshops (GC Wkshps), 2011.

[4] S-Y. Lien, T-H Liau, C-Y Kao, K-C. Chen; “Cooperative Access Class Barring for Machine-to-Machine Communications”. IEEE Transactions on Wireless Communications, Vol. 11, No. 1, January 2012

3.2. The effect of using RACH for scheduling of event-based traffic in LTE-A networks (LTU)

In this work we investigate the performance of LTE network (3gpp Long Term Evolution) when using it as a radio bearer for sensory data traffic. We consider the case where sensor nodes are equipped with the LTE interface and use this interface to communicate their measurements.

In LTE network all users are allocated equal resources in a specialized signalling channel (PUCCH), which are to be used for scheduling requests. If in addition to conventional user equipment new type of sensory devices would use this channel for sending their scheduling requests, the primary users will experience notable delays in connection establishment. In this work we consider scheduling of m2m sessions exclusively over the RACH channel.

In particular, we improve the probabilistic network-level model of Multichannel Slotted ALOHA [1]. We further use the model to study the effect from signalling originated by a large scale event-based sensory application on the performance of the RACH channel.

[1] Z. Liu and M. El Zarki, “Performance analysis of DS-CDMA with slotted aloha random access for packet PCNs,” Wirel. Netw., vol. 1, pp. 1–16, February 1995. [Online]. Available: http://dx.doi.org/10.1007/BF01196254

3.3. Simulation techniques for m2m communications in 4G networks (BUT)

Simulation of the LTE and LTE-Advanced link level performance. Performance curves (Bit/Block Error rate, throughput) for different channel models (ITU Vehicular and Pedestrian type A, B, Wiener channel model) can be used for system level simulation of the heterogeneous M2M networks. Implementation of the application-aware radio resource management leads to improved Quality of Experience. Experimental verification of the physical layer abstraction for the system level simulation can be found in [1] with video streaming application over OFDMA based air interface.

Next steps towards full LTE-Advanced specification implementation to the link level simulation. mainly interest in the uplink part is our goal. Link level simulation of the OFDMA based system can be extended by vehicular channel models for high speed scenarios (possible input from partners?).

[1] Florian Wamser, Dirk Staehle, Jan Prokopec, Andreas Maeder, Phuoc Tran-Gia: Utilizing Buffered YouTube Playtime for QoE-oriented Scheduling in OFDMA Networks, submitted to ITC 2012

4. Local short-range dependable m2m communication

This section elaborates the technologies and the state of the art in the area of infrastructure-less m2m communications

4.1. M2M for intra-vehicular communications (LTU, VTT)

- Wireless data transmission in a vehicle.
- Wirelessly connect moving parts of industrial vehicles
    - For better reliability and usability in comparison to existing wired solutions
    - For solutions that are more robust (from the point of view of rf disturbances as well as normal environmental conditions), cause no interference, build up a reliable, redundant network and are, of course, safe from the point of view of people working around the machine.
    - Possibility to extend intra-vehicle communication to include components outside the vehicle. For example external devices connected to the vehicle or humans working with the vehicle or near the vehicle.
- Communication between vehicles or vehicle and infrastructure.

4.2. M2M for inter-vehicular communications (UTwente)

A special form of M2M communications, especially within the context of Wireless Networking for Moving Objects (WiNeMO), is communications between vehicles. Typically, inter-vehicular communications is designed with the aim of creating Intelligent Transportation Systems (ITS), although it can also be used for other purposes, such as entertainment. ITSs are being designed, mainly with 3 objectives:

- to increase traffic safety,
- to increase traffic efficiency, and
- to reduce emission from traffic.

Here, we will focus on inter-vehicle communications to support the cooperative control of the movement of the vehicles. An example of this is a so-called Cooperative Adaptive Cruise Control (CACC), in which longitudinal movement of vehicles is cooperatively controlled by the vehicles (and possibly the roadside).

Two basic modes of communication for enabling cooperative movement of vehicles can be identified:

- beaconing: periodically declaring basic information such as location, velocity, acceleraion to neighboring (1-hop) vehicles
- geocasting: forwarding messages, possibly over multiple hops to a/all/any node(s) in a specified geographical area.

Beaconing is typically used to feed a part of the controller (object tracking) with up-to-date information about location, velocity, and acceleration of surrounding vehicles. With this information, the object tracker can predict future location/speed of relevant vehicles, and determine its required speed / acceleration (or deceleration). Typical beaconing rates are in the order of magnitude of 10 Hz per vehicle.

For a CACC, geocasting is used in merging situations, where traffic in certain lanes has ts to be warned about upcoming merging actions of vehicles into those lanes, so that they can free up space for mergers.

Many research issues w.r.t. these communication modes can be identified:

- adaptive beaconing (adapting rate and range/transmission power of beaconing to network load),
- dealing with hidden terminals,
- multiple access mechanisms (IEEE 802.11p uses CSMA/CA, alternatives have been proposed),
- forwarding rules for geocasting,
- constrained geocasting (the geocast area is subject to constraints and can only be determined during the forwarding),
- piggybacking of geocast messages on beacons, and
- modeling of beaconing and geocast protocols.

4.3. Cognitive M2M communications

Due to spectrum limitations, wireless M2M communications must efficiently utilize the available spectrum. As the traditional static spectrum allocation techniques do not yield satisfactory optimal spectrum management, a cost-effective solution being widely pursued is the innovative use of *cognitive radio (CR)*. CR is capable of enabling dynamic and flexible access to potentially large portions of already licensed but unused, or poorly utilised, spectrum (e.g., TV white spaces, TVWS). This especially holds out important promise for smart grids and intelligent transportation systems, which require universal coverage in order to connect millions of meters or vehicles to service-side monitoring and control systems. Furthermore, the development and use of CR’s interoperability features will enable operators to provide *horizontal* M2M solutions for a range of applications, in addition to the current vertical solutions.

The potential resource of TVWS – the unused portions of spectrum in the TV bands – opens various possibilities for new services and business models due to their very long radio range, low CAPEX (fewer base stations needed for same coverage), reduced OPEX, licence-free operation, and excellent in-building penetration. Before operating, however, TVWS devices must establish which frequency channels are available and at what particular times and locations. Various CR techniques for identifying unused spectrum are possible, e.g., beacons, spectrum sensing, and geo-location. Of these, using a geo-location database is the most promising one (spectrum sensing performed by each machine seems not economical), and is the method currently being pursued by regulators in the USA and the UK. Besides its more orderly effectiveness, it’s ‘greener’ in that its pro-active distribution/broadcast of database information about spectrum opportunities via a cognitive pilot channel (CPC) to all devices in a targeted area results in reductions in overall energy consumption.

The CPC component, in particular, could be also explored for use by remote maintenance and control M2M applications. In ensuring better and more appropriate service to consumers by anticipating and responding to their problems, companies may reduce their costs by upgrading software features of their devices remotely, by sending out over CPC urgent software updates and repairs and, by doing this, to automate the supply chain. Device manufacturers and service providers will profit from the new-found CPC ability to keep devices up and running and to pro-actively respond to consumer needs (e.g., provide software for SDR reconfiguration purposes). Consumers will benefit from knowing that their products and devices are always accessible and always operating, which will allow them greater and more complete mobility, and enhance their control over their environment.

Smart grid / smart metering and distribution automation are just one of many applications of TVWS. For municipal utilities, other applications may include traffic monitoring, street lighting control, connectivity for electric vehicle charging points, etc.

Secondary spectrum markets, which provide use of the spectrum to entities other than the original license holders, should be well-functioned to ensure that available spectrum will migrate to more efficient usage. Challenges lie in how to build up a well-behaved secondary market. Also, as any increase in spectrum efficiency may result in an undesirable increase in power consumption, new techniques are required to find out the best compromise between power efficiency and spectrum utilization in different operating environments.

4.4. Other cases for local communications

Should be further discussed during the meeting.

5. M2M management

Open problems in area of management are:

- How to identify a device in M2M area?
- How to address a device in M2M area?
- How to provide a (new) software/service to device in M2M area?
- How to change a M2M Application Provider for already-deployed equipment in M2M area?
- How to change software on a M2M Gateway without stopping the service?
- How to synchronise different devices in M2M area?

Some problems are partially solved by standards ETSI and 3GPP. We are focusing on the following areas:

- Mechanisms for software provisioning and configuration management, especially for already-deployed equipment without visiting the equipment (remotely). In the ETSI architecture the M2M Gateway is point between communication network and M2M Area network (network with devices, sensors, etc.). We use for M2M Gateway Android mobile telephone onto which mobile OSGi is installed. Software provisioning and configuration management is accomplished using mobile OSGi which is compliant with OMA DM.
- Mechanisms for identification, addressing and software management of device behind firewall/NAT/router or M2M gateway. There are two cases regarding what is in place of M2M gateway. There is either M2M gateway that is compliant with standards or standard

equipment like router/firewall/NAT. If there is standard equipment then the M2M device behind it can not be addressed from network side because M2M device has private IP address and it is not addressable. One way is to reconfigure standard router but it is not viable option. In case when the M2M device is equipped with communication module with mobile network (e.g. 3G) then the SMS can wake up device and trigger opening connection to the M2M Application domain.

- Synchronization process in heterogeneous Machine-to-Machine (M2M) systems is problem when M2M devices are wireless and depend on batteries. In that case the M2M device after communication must turn off communication module in order to save energy. While it is turned off the communication is available. In order to enable communication between M2M devices in ad-hoc way they must be synchronized to turn on communication in the same time. To do that in distributed heterogeneous environment we are using self-organized and bio-inspired mechanisms based on fireflies. Fireflies are formalised on pulse-coupled oscillators.