Machine-to-Machine communication in LTE-A

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Abstract—**Wireless equipped machines are increasing greatly in the recent years, among which the cellular network based machine-to-machine communication (M2M) has shown the advantages of better coverage and lower network deployment cost. However, the current cellular network is designed for human-to-human communication, targeting the voice/media transmission with low access delay and high throughput, so the machines in GSM and UMTS are designed like the screenless phones. To extend the market to the machine type communication, it is envisaged that the specific optimizations for M2M will be introduced in LTE-A, especially when M2M communication accounts for the considerable part in the total networking activities. In this paper, some of the considerations of the network side improvements are presented, from the physical layer, MAC to the core network.**

Keywords- Machine-to-machine; cellular based M2M; LTE-A

I. INTRODUCTION

Machine-to-machine communication will be one of the focuses in LTE-A, as the demand of M2M is increasing so greatly recent years and might eventually exceeds the human-to-human communication. The reason is that there are 50 billion machines in the world, but only 6 billion people. There are already some applications in GPRS/UMTS networks, e.g. metering and security alarm system. Some commercial cellular based M2M solutions and modules can be found in the market [1] [2]. The typical hardware architecture of such modules includes the GSM/GPRS module, extension slots, USB, memory, CPU. The software installed may include TCP/IP stack, Java support and other software platform for development new applications. In short, such modules are more like a screenless mobile phone rather than a sensor. The cost would be slightly cheaper than a mobile phone, but significantly higher than the devices in Zigbee networks. This leaves a big obstacle of large scale deployment and then the type of applications is limited.

Some recent papers discussing cellular based machine to machine communication also focus on the integrated solution which is similar to the existed industry products [3] [4]. In [3], details about management of GPRS based M2M are discussed. In the given architecture, the solution is based on the mature M2M module from different venders. In [4], the improved M2M platform for multi-sensor application is discussed. A hardware prototype is given that includes the GSM/GPRS module, Ethernet module, Bluetooth module, memory and RS232 interface. Such a solution has the same complexity as other M2M products mentioned in previous section. In this paper, we propose a solution that minimizes the functionalities needed to access the cellular network for the machines, which makes the devices much smaller and of low cost.

Till now, there is little improvement to the M2M market. Like the first generation M2M, a major part of M2M uses SMS as the communication method, and the machines only send small amount of data once a time. It is not a problem when there are few machine devices in the network. SMS accentually is a compromise to transmit data in the GSM network. Keep in mind that now LTE has the architecture of everything over IP. The SMS itself will be transmitted in a different way. To transmit a small amount of data, the efficiency is very low via TCP/IP, because the overhead of the protocols and the signaling procedures to establish radio and network bear can be as more as hundreds of bytes. Hence, the efficiency issue becomes one of the challenges to M2M.

If we have a look at the study report of 3GPP TR22.868, we can find the envisaged M2M applications are so various, from bit level communications, e.g. metering, to high bandwidth consuming applications such as video surveillance. It is impossible to develop a unique platform to support all these applications in an economic way. For example, the metering device is desired to be simple but the video surveillance device needs different and powerful codec, different protocols and would have different radio capabilities. If we have to use only one solution or hardware platform for all the services, the consequence is the machine will be very complex, just like a smart phone today.

Another significant difference between human and machine is that the machines are application specific, e.g. quite a lot of machines are fixed on a equipment to monitor or meter some signals, and then these machines may probable never move. This means the network can always know where it is and as a consequence the paging and other mobility management issues can be simplified or omitted. From the machine side, the mobility assistance procedures e.g. measurement reporting, can also be redundant or never happen.

The paper is organized as follows. In section II, the idea of customized M2M physical layer is discussed. Then we discuss the MAC protocol in section III. The network side optimization for M2M is presented in section IV, followed by the conclusion section V.

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II. CUSTOMIZED PHY LAYER

As analyzed in section I that the M2M solution for LTE-A should provide sufficient scalability and flexibility to adapt to the applications. A straight forward motivation is to develop a low complexity and low cost device for metering and powerful one for video surveillance. However this is not allowed in the current specification. In current specification, only very limited categories of handset capabilities are supported, and even the lowest category can provide what's more than the metering needs. Hence, the metering device nowadays is still a screenless handset, which sets the obstacles to further reduce the cost, as well as battery consumption. The reason behind this is that the functions including voice, SMS and some limited web browsing, are almost indispensable for every phone module.

If it is allowed to design the M2M from the scratch, one may deduce the needed capabilities according to the specific application type, as shown in Fig. 1. For example, if a metering machine is needed, which is permanently fixed on industrial equipment and only very small amount of data is sent to the remove control center occasionally. The downlink control is not needed for this application. Thus, we can formulate the needed physical layer capabilities, for example narrow bandwidth down to 1.25MHz, maximum transmission power limited to 3dBm like ZigBee.

A possible implementation flow is to combine the optimal configuration with current LTE network requirements in a reasonable way. Here, we propose the idea of customized physical layer. As shown in Figure 2, the LTE-A physical layer chain contains the following six function blocks, including physical channels supported, coding schemes, modulation schemes, maximum transmission power, bandwidth configuration, RF configuration, e.g. EVM and antenna. A normal handset would generally support all the options, e.g. support both convolutional coding and turbo coding. However, a vendor of M2M may choose to implement only one option of a block, e.g. only convolutional coding. The only requirement is every the physical layer chain should be complete, i.e. every the machine should support at least one configuration of each block. Therefore, by the combination of all these options, there could be hundreds of categories of machines. If the upper layer capabilities are also considered, there will be even more types of machines.

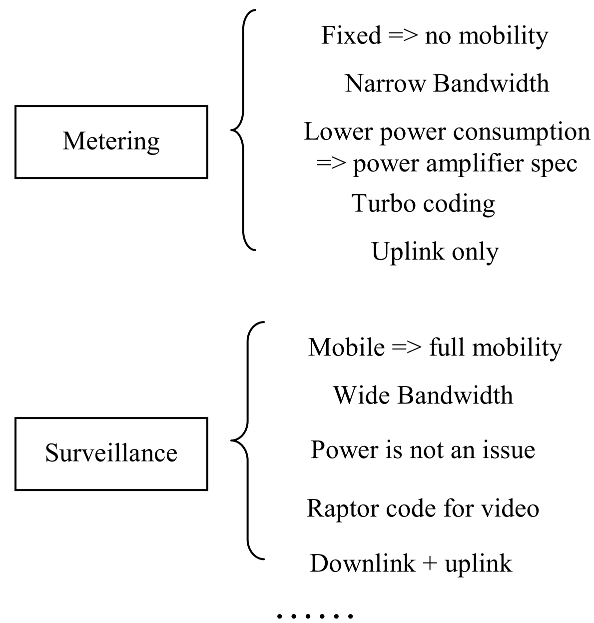

Figure 1. Evaluation sheet of a specific machine application

The benefit of customized physical layer is that the machine now has the optimal configuration of a specific application, so the hardware platform and the cost could be well controlled. The second benefit is the vendor can use their strong point to configure the machine hardware solution. For example one vendor in the leading position of transmission filter design, it may use a better transmission filter meanwhile with competitive cost. Finally, the machine is LTE-A capable, because all these function are supported by LTE-A, and no new technique is introduced.

Since these machines are deployed by large company, it is easy to make the conformance test of the new devices, so network operator does not need to worry the impact on the current network.

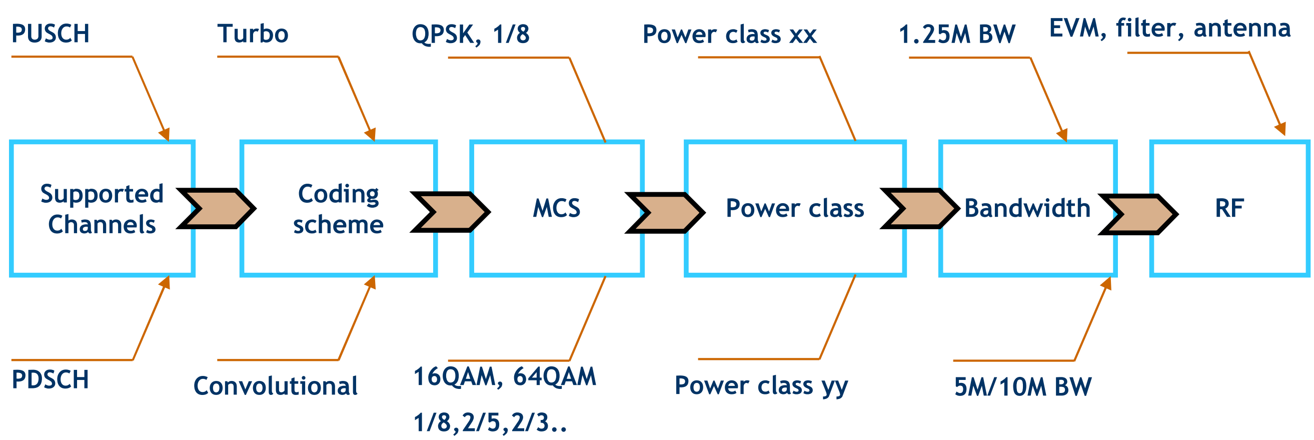

Figure 2. Customized physical layer

III. OPTIMIZED MAC

Here we focus on the machines with small amount of data for transmission, because the video surveillance machine may have to be as complex as the current solutions. For the low data transmission machine, the efficiency is an issue. It is too wasteful to establish RRC connection, network connection to transmit several bits. Hence, the MAC layer protocol needs just to be reconsidered to accommodate the data transmission directly during the uplink accessing stage.

Fig. 3 shows the procedures in the data transferring option A, with the new procedures highlighted. When received the uplink preamble, the BS allocates UL resource to accommodate the uplink radio RRC setup request. Now, we use the MAC PDU which should carry the RRC signaling to carry the data. The eNB can recognize the MAC PDU, because it is a special MAC format which is used to identify the special MAC PDU which does not carry a RLC PDU. It is noted that there is no RRC setup request message on the allocated resources. The connection will be limited on MAC level. The RLC/RRC/PDCP entities are not used in the communication. In this scheme, the terminal does not need to support the complete RRC protocol, which is quite complex. Especially, the uplink request and data transmission can be limited to the MAC level. For downlink, the terminal only supports just a few information elements of several RRC messages, e.g. what's in the broadcast channel.

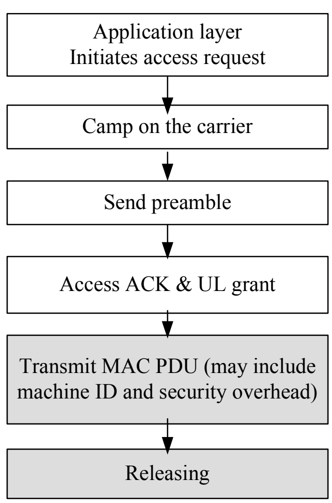

Figure 3. MAC protocol option A

The MAC protocol may further reduced, as shown in Fig. 4. The data is transmitted to BS by a special access preamble, or predefined preambles followed by the first access preamble. The terminal does not need to establish the RRC connection, and even does not need to transmit the data via the uplink channel scheduled by the BS, as the data is sent on RACH directly, after encoded as a special preamble. When the eNB has received the data, an ACK is sent back. Finally the machine can decide whether the connection with eNB needs to be released.

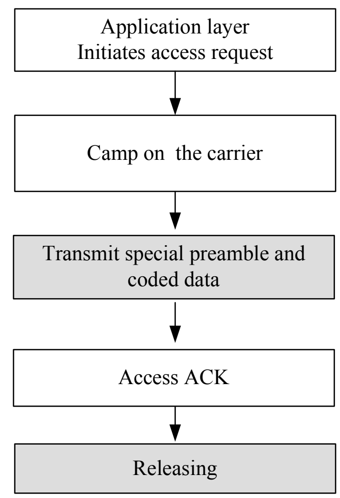

Figure 4. MAC protocol option B

The common point of the above two options is the machine does not need to perform any mobility procedures. It is not needed to report the measurement of the neighbor cells, and it is also not needed to update its tracking information to the core network. The machine is not pagingable.

IV. NETWORK SUPPORT OF M2M

In a practical scenario, the sensors communicate with their proxy and the proxy forwards the data to the network. The benefit of such a scheme is that the sensors could be kept further simple and lower power consumption. The proxy may store the data from the sensors and package them into a single packet and forward to the network. Since one transmission needs to set up one uplink accessing procedure, including authentication and TCP/IP flow, etc. It is desirable that the proxy can package the data into one packet to reduce the signaling overhead. The data then is forwarded to the dispatcher, which set up the connection with each server indicated by the packet header of from the proxy PDU. The proxy assumes that it still communicates with the M2M server by connectionless protocols, but in fact its data is forwarded by the dispatcher. The M2M terminal does not need to be aware of this. In fact, the M2M terminal only communicates with BS. The dispatcher not only forwards the data from the terminal to the server, but also acts as a virtual interface between the terminal and the server. The M2M server considers the data is from the terminal directly. Therefore, the proxy/dispatcher can be seen as the extension to the terminal, which is located inside the network.

The work flow is:

1. The M2M terminal generates the sampled data, e.g. chemical information of the area and processed at application layer.

2. The M2M terminal sends the data to the proxy.
3. The proxy receives the data and stores it.
4. The proxy receives the data from other sensors and checks whether it is urgent. If the data is not delay tolerant, the proxy will access the network to forward it immediately; if not it will keep in the pending state.
5. The proxy periodically packages the data from different sensors in a predefined format (to be specified), where the server ID and sensor ID are included together with the data.
6. The proxy accesses the network and sends the data to the dispatcher.
7. The dispatcher acknowledges the proxy. The dispatcher interprets the package and recovers the data in it including the signaling.
8. The dispatcher establishes the connection with the server according the server ID.
9. The dispatcher forwards the data to the correct server.

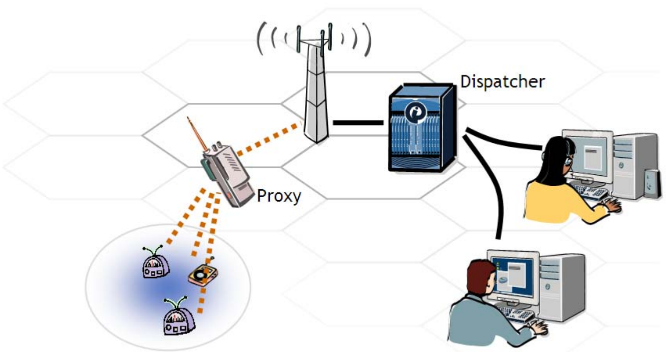

Figure 5. Proxy and dispatcher

In the following part, the MAC based solution is studied further. First we compare the signaling overhead performance. The terminal should attach to the network first, and meanwhile a default EPS bearer is established. Then the UE can generally send simple data after setting up the connection with the remote server. Then the data is transmitted by tunneling protocol through core network and then to the server via IP network. We choose the FTP service, which is considered similar to the machine applications. The FTP is configured to upload a 128 bits file. TCP/IP and core network protocols and procedures are also considered, but only uplink signaling is analyzed.

The results are shown in Fig. 6. Quite a lot of signaling overhead is needed for the terminal to attach the network, including attach request and completion signaling. After this, the service request is sent. In the above steps, the total signaling exceeds 1000bits. Finally, the TCP/IP protocol procedure and data transmission can start, followed by the corresponding completion signaling at layers. Hence, the efficiency to transmit the 128bits data in this step is lower than 10%.

For the proposed solution, only a simple request is sufficient. If successful, the data will be transmitted directly. The benefits are obvious, short delay and less overhead.

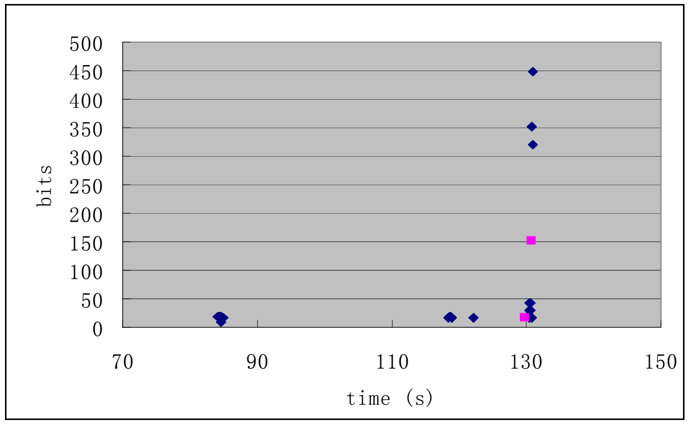

Figure 6. M2M signaling overhead chart

V. Conclusion

In this paper, we present our ideas of the M2M communication in LTE-A. The complexity and the signaling overhead are the key issues. As a tradeoff, the capability negotiation mechanism is proposed, by which the machine design will not be constrained to the limited number of the UE category. Moreover, the MAC protocol is also discussed with possible enhancements, followed by the analysis of the scheme of proxy-dispatcher entity in the core network which reduces the signaling overhead at the network side.

References

[1] Curran, Ian; Pluta, Steve, “Overview of machine to machine and telematics”, Water Event, 2008 6th Institution of Engineering and Technology, 22-23 April 2008, pp. 1 – 33

[2] Conti, J.P., "The Internet of things", Communications Engineer, Volume 4, Issue 6, Dec.-Jan. 2006, pp. 20 – 25

[3] Martsola, M.; Kiravuo, T.; Lindqvist, J.K.O., "Machine to machine communication in cellular networks", Mobile Technology, Applications and Systems, 2005 2nd International Conference on, 15-17 Nov. 2005

[4] Cristaldi, L.; Faifer, M.; Grande, F.; Ottoboni, R., "An Improved M2M Platform for Multi-Sensors Agent Application", Sensors for Industry Conference, 2005, 8-10 Feb. 2005, pp. 79 – 83

[5] 3GPP TS 22.368, Service requirements for machine-type communications, verion 1.0

[6] 3GPP TR 22.868, Study on facilitating machine to machine communication in 3GPP systems, version 8.0