EXALTED SYSTEM ARCHITECTURE

Aleksandar Obradović[1], Nenad Gligorić[2]
[1]Telekom Srbija a.d.
[2]Ericsson Serbia

Abstract: *The development of machine-to-machine (M2M) technology and communication standards ensures M2M devices and networks interoperability, lowers the production costs and rapidly expands the M2M market. This paper is focused on the system architecture that is being developed in EXALTED (EXpAnding LTE for Devices). EXALTED is EU FP7 framework project which goal is to create a standard for M2M communication over the LTE network. This work will present overall EXALTED system architecture and mapping of the EXALTED architecture into the ETSI and 3GPP framework. Interaction between the different M2M domains (network and device domain) will be presented as well.*

Key words: *machine-to-machine (M2M), M2M architecture, EXALTED system*

1.Introduction

This paper introduces the EXALTED system architecture. Following a thorough investigation of the most emerging M2M applications and use cases, the most critical requirements (e.g. functional requirements, network requirements, and service requirements), were identified towards the development of the necessary corresponding algorithms, procedures and technologies. The system architecture aims to provide a coherent framework, ensuring that all technical innovations are aligned towards a unified system concept, able to achieve the project's objectives.

The work in EXALTED is founded on two existing proposals that are considered as baseline architectures, namely 3GPP MTC [1] and ETSI M2M [2].

However, for the achievement of the EXALTED objectives, it is not sufficient to adopt ETSI M2M or 3GPP MTC as they are and the necessary enhancements at the Network Domain (ND) and the Device Domain (DD) were identified, in order to leverage on these standardization efforts and complement them with new sets of features needed to provide cost, energy, and spectrally efficient connectivity to devices.

The working assumption for the EXALTED architecture is that it consists of various components characterized by their functionalities.
A component can either be a physical entity, e.g. a M2M device, or a logical element summarizing certain functions that are in reality distributed at different locations, e.g. the Evolved Packet Core (EPC).
The functionality of a component can be realized by algorithms, and interfaces can be implemented with certain protocols.
The scope of EXALTED is to contribute to the existing standards and take advantage of existing solutions. To this end, the EXALTED architecture has adopted specific parts of the aforementioned architecture, as follows:

- The 3GPP Core network (i.e. MME, SWG/PGW, MTC-IWF, etc)
- The ETSI Service Capabilities concept

2. Baseline architectures for EXALTED M2M Architecture

Two baseline architectures are considered for the work in EXALTED, namely 3GPP MTC [1] and ETSI M2M [2]. 3GPP MTC mainly focuses on the communications, while ETSI M2M focuses on the applications.
For example, in the 3GPP architecture the E2E aspects of communication between MTC devices and MTC servers, or the functionalities provided by the MTC Server itself are out of scope [1]. On the other hand, ETSI architecture does not specify the Radio Access Network (RAN) that links the DD with the ND [2]. The EXALTED architecture can be considered as an enabler, based on 3GPP MTC, for specific Service Capabilities required by ETSI M2M-based applications.

3. LTE and LTE-M compatibility in EXALTED

Within the scope of EXALTED, and for the purpose of LTE-M specification, changes (innovations) occur at the following elements:

- UE (User Equipment),
- ebb (encode B) and
- Uu interface (UMTS interface between UE and UMTS Terrestrial Radio Access Network).

Moreover, considering the LTE layers, changes are made to: L1, MAC, RLC, PDCP, and RRC. The IP layer can also exist at eNB user plane, for the purpose of IP termination in case of non-IP capable LTE-M devices directly attached to eNB.
On the Figure 1 we can see High level system diagram of the EXALTED system.

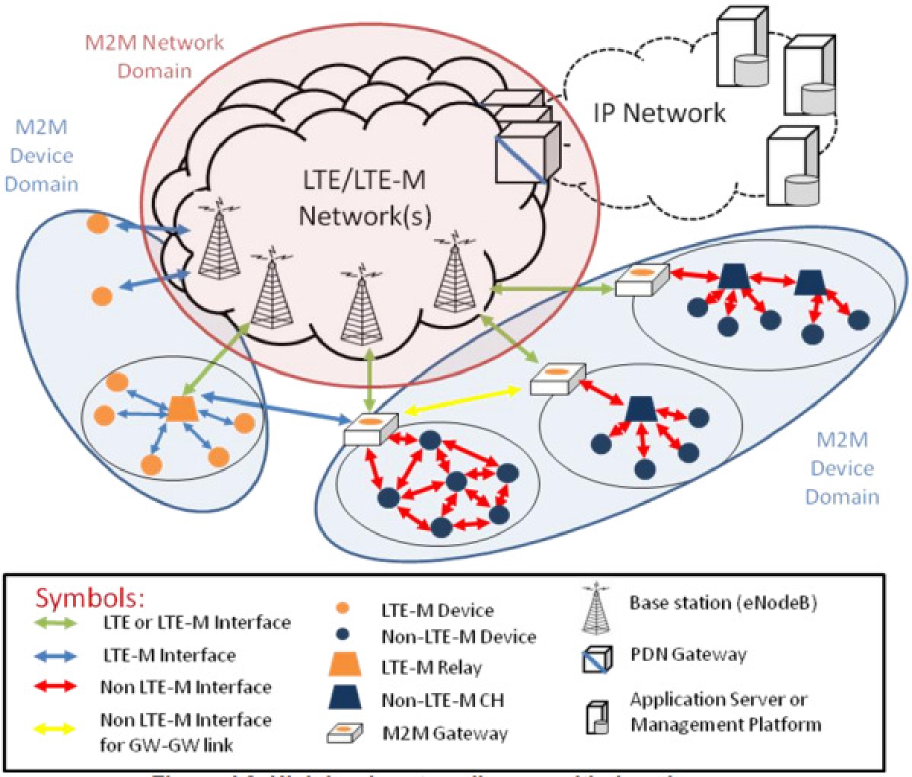

Figure 1. *High level EXALTED system*

In general, IP connectivity in EXALTED is feasible between any IP capable end-points, if their IP addresses are globally routable, or locally in the IP based capillary network.
In particular, the following IP connectivity modes are available:

– M2M Server ↔ PGW ↔ IP device (end device or a GW);
– M2M Server ↔ PGW ↔ eNB *;
– M2M Server ↔ PGW ↔ GW ↔ IP capable non-LTE-M end device **.

** GW and some LTE-M devices would have this capability, and eNB would record it, and perform forwarding of IP packets to IP UEs, and a decapsulation/mapping into C-RNTI identifier for non-IP UEs.*
*** If the device has globally routable IP address, or using NAT on GW.*

4. Components of the EXALTED system architecture

In Figure 2, the EXALTED architecture is depicted, along with the major innovations compared to the ETSI and 3GPP proposals (green colour). A component is either a physical entity, e.g. an LTE-M device, or a logical element summarizing certain functions that are in reality distributed at different locations, e.g. the Evolved Packet Core

(EPC). The Core Network is depicted in more details in Figure 2, illustrating the relation with the 3GPP MTC approach and the backward compatibility with LTE. EXALTED has adopted the indirect 3GPP model, which assumes that the MTC Application does not connect directly to the operator network without the use of any MTC Server.

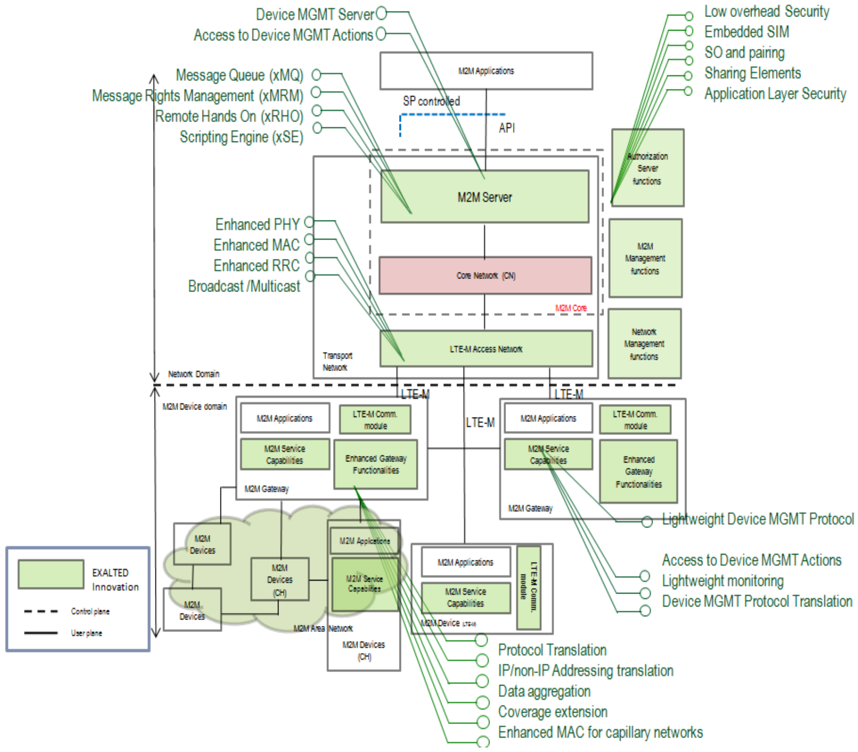

Figure 2. *EXALTED architecture*

5. EXALTED domains

We classify the EXALTED architecture in two domains, namely, the *Network Domain* (ND), and the *M2M Device (and Gateway) Domain (DD).*

All components whose functionality is related with the control of applications, security and the management of devices belong to the ND. In EXALTED the wide area Access Network is restricted to the LTE-M/LTE system. Moreover, the EPC responsible for the management of cellular radio network and the eNB in the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) are part of the ND. We assume that the application may run on a M2M server accessible from the internet using the EPC. In the network domain reside also the logical components, which are responsible for specific functions, such as the authorization and management of devices and network components.

The DD includes all kinds of devices that support one or more applications. The link between DD and ND is the Uu interface defined in 3GPP. However, the used air interface is not LTE, but LTE-M, an autonomous radio access network coexisting with LTE in the same spectrum [3].

The EXALTED architecture shall support the communication between different types of devices and various use cases, and not the complete functionality is required for all of them. A high-level view of the EXALTED is depicted in Figure 3.

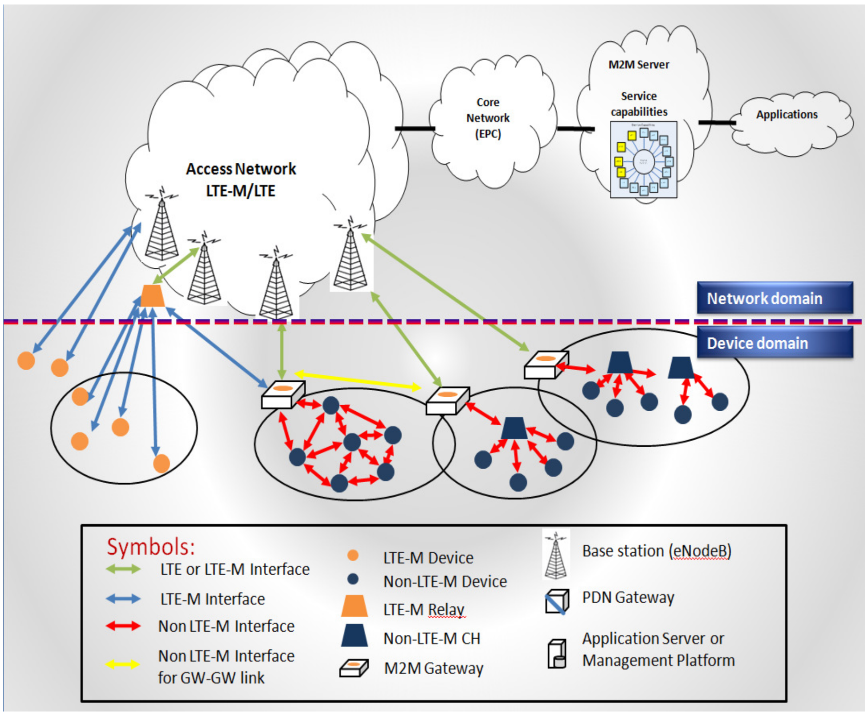

Figure 3. *High level EXALTED architecture*

In the following we present the components belonging to the two domains ND and DD and explain those parts of their functionality that will be implemented by EXALTED algorithms

6. Components in ND

The functionalities of the components in the ND are related with the control of applications, security and the management of devices. Additionally, in the same domain reside those logical components, which are responsible for authorization functions. In the following subsection, the functionalities of the ND components are presented in details.
M2M Server is a logical component, i.e. it has not been implemented on single equipment. On the top of the underlying protocols and technologies, particular M2M Servers communicate with M2M Devices and Gateways that are involved in the same application. Note that the applications may run on any functional element in the DD (i.e. on the M2M Gateway, the M2M Devices, or the Cluster Heads). Apart from the application itself, management and control functionality is part of the M2M server, such as Device Management, which uses specifically designed protocol over the same network

for communication with Devices and Gateways, and servers needed to fulfill the security requirements.
The EPC consists of Packet Data Network gateway (PDN-GW), Serving gateway (SGW), Mobility Management Entity (MME), Home Subscriber Server (HSS), and Policy Control and Charging Rules Functions (PCRF). EXALTED does not intend to propose any changes in the EPC. Therefore, its functionality is not explained in this paper, and it is referred to [4], [5], and [6].
LTE-M PHY, MAC and RRC Tx and Rx algorithms must be implemented at the eNB in order to support respective protocols of the LTE-M Uu interface. The most important functions are: error protection and correction, provision of random access and scheduled access to radio resources in time and/or frequency utilized for the payload and control signalling, transmission of pilot signals for channel estimation, initialization and control of re-transmission processes, connection set-up and finalisation, synchronisation between transmitter and receiver, adaptation of the radio link parameters to the propagation conditions, and support of broadcast und multicast services.
One possible realization option of LTE-M is to provide a radio interface purely consisting of PHY, MAC, and RRC protocols. For this purpose, the IP protocol normally executed between PDN-GW and UE has to be terminated at the eNB, where IP addresses are translated into a local addressing scheme and vice versa.
In the case, where the eNB has a connection to an M2M gateway, it must be able to aggregate data packets addressed to several Non-LTE-M Devices behind the M2M gateway into one compound data packet, either IP based or non-IP based.
These elements are similar to 3GPP rel.10 LTE-A Relays. They are used in LTE-M environment for coverage extension and communication with the rest of the network. Both transparent and non-transparent Relays are supported within 3GPP. The required functionalities depend on the relay type (L1, L2, or L3). The LTE-M relays have the very same functionalities as the LTE ones with the additional capability to support the LTE-M interface.

7. Components in DD

In DD there exist devices that utilize the LTE-M air interface (LTE-M enabled) and devices that do not (non LTE-M enabled). The M2M gateway has a key role in the EXALTED architecture, because it is the link between the cellular radio network (LTE-M) and connected capillary networks. It enables reliable E2E connectivity between a simple Non-LTE-M Device and the M2M Server, i.e. the application being executed in the internet, which is one of the key objectives in EXALTED.
LTE-M devices have LTE-M interface and can access the Network domain, either by directly accessing the LTE-M network, or through an LTE-M Relay.
M2M Gateway provides the interconnection between the LTE-X (i.e. LTE/LTE-A/LTE-M) network and the capillary networks (consisting of one or more M2M devices). It can provide various functionalities, such as protocol translation, routing, resource management, device management, data aggregation, etc. In some cases, the gateway may provide M2M services without requiring accessing the core network, which is however out of scope of EXALTED. It is expected that the M2M gateway will normally connect to the LTE-X network with a direct radio link. In the case that an M2M gateway is unable to establish direct connectivity (for example, due to deployment in a remote area without

coverage, or due to localised infrastructure failure) connectivity to the LTE-X network may be achieved by hopping via an LTE-M Relay and/or one or more other M2M gateways. The availability of direct M2M gateway to M2M gateway links will depend on the capillary radio network interfaces supported within the gateways. LTE-M will not support such links. Direct M2M gateway to M2M gateway connectivity for the purpose of E2E device to device connection without any LTE-X involvement (e.g. local breakout) is not the primary focus of EXALTED.

Non LTE-M devices do not have an LTE-M interface, but form capillary network(s) using other network access technologies, such as Zigbee, and IEEE 802.11x. They can access the Network domain through a M2M gateway, and run M2M applications locally.

Non LTE-M CH can be considered as M2M devices with some additional capabilities. Like regular M2M Devices, they are also part of capillary networks and the communication from a regular M2M Device may be directed through and managed by a CH. The functionalities of a CH may include data aggregation, device management, routing, etc. Unlike an M2M gateway, a CH will not perform protocol translation. Most of the functionalities of CHs are protocol specific, and depend on the particular protocol running in the capillary network.

8. Supported communications scenarios in EXALTED

The communication between the elements can be one of the following two general types, with their corresponding communication modes:

- Communication of Devices with Application Servers in the IP network (Type 1):

  <u>LTE -M Device ↔ Application Server</u>: This is the simplest mode of communication, where the application data is directly encapsulated into the LTE-M protocol stack, and forwarded over the LTE-M network from a Device to a Server, and vice versa.

  <u>LTE-M Device ↔ LTE-M Relay ↔ Application Server</u>: In this type of Communication, the application data is directly encapsulated into the LTE-M protocol stack by the Device and the LTE-M Relay forwards the data over the LTE-X network to the Application Server. The equivalent process occurs in the other direction.

  <u>M2M Gateway ↔ Application Server</u>: This is a similar case to the first communication mode. If an application is running on an M2M Gateway, it communicates directly with the Application Server over LTE-M network.

  <u>Non-LTE-M Device ↔ M2M Gateway ↔ Application Server</u>: In this case the M2M Device is part of a capillary network that is not LTE-M, and the access to the LTE-M network is realized through an M2M Gateway. The application data is sent by the M2M Device to the M2M Gateway, which performs protocol translation from the capillary network protocol to the LTE-M protocol stack and vice versa. The application data is extracted and re-encapsulated by the M2M Gateway.

  <u>Non-LTE-M Device Group ↔ Application Server</u>: It corresponds to broadcast/ multicast traffic to a group of Non-LTE-M devices. Application data is encoded using network coding.

- Communication between Devices (Type 2):
  LTE-M Device ↔ LTE-M Device over LTE-M network: LTE-M Devices or LTE-M Gateways communicate over the Base Station(s) and the LTE-M Transport and Core network. Each PDN connection must be terminated at the PDN Gateway, so a Device-to-Device communication actually consists of 2 steps: Device-to-PDN Gateway and PDN Gateway-to-Device communication.
  LTE-M Device (standalone) ↔ LTE-M Device in a capillary network: LTE-M Devices communicate over LTE-M network and PDN Gateway, and the LTE-M Relays forward data to/from LTE-M devices which it is in charge of.
  LTE-M Device ↔ LTE-M Device in the same capillary network: Since each communication between LTE-M Devices must be established via the LTE-M network and PDN Gateway, devices in an LTE-M capillary network cannot communicate directly.
  Non-LTE-M Device ↔ Non-LTE-M Device in the same capillary network: In this simplest case devices exchange information directly, i.e. the network is not aware of it. This type of communication is possible only if the capillary network protocol allows it.
  Non-LTE-M Device ↔ Non-LTE-M Device in different capillary networks: This is the most complex case of Device-to-Device communication. Devices exchange application data, but since they are not in the same capillary network they must forward the information to their M2M Gateways, which perform the protocol translation, route the traffic (over the LTE-M network, i.e. the PDN Gateway is included) to the receiving M2M Gateway, who then again translates the information to the destination device.

9. ETSI, 3GPP and EXALTED terminology equivalences

ETSI, 3GPP and EXALTED each follow a slightly different terminology for broadly similar architectural elements. The most important architectural elements from each approach can be found in Table 1, with the equivalent EXALTED terminology indicated. It should be noted that the role and functionalities of each element are not necessarily identical across the different architecture, but this table should assist those moving from one architectural description to another.

3GPP terminology	ETSI terminology	Equivalent EXALTED terminology
MTC Server	M2M Service capabilities (SC)	M2M Server
MTC Application (UE)	M2M Application (Device)	M2M Application (Device)
-	M2M Application (M2M Gateway)	M2M Application (M2M Gateway)
-	-	M2M Application (CH)
MTC User	M2M Device	• LTE-M Device • Non-LTE-M Device
EPC	Core Network (CN)	EPC
RAN	Access Network	LTE-M Access Network
eNB	-	eNB
Relay Node (RN)	-	LTE-M Relay
-	M2M Gateway	M2M Gateway
	M2M Area Network	M2M Capillary Network

Table 1. *ETSI, 3GPP and EXALTED terminology*

10. Summary (Conclusion)

The natural ecosystem of EXALTED is to be found within the 3GPP LTE specifications, with the main scope being to leverage and enhance the 3GPP MTC Architecture. Although the focus of EXALTED is on M2M communications, the ETSI M2M system has been also taken into account, and the ETSI M2M functional specifications are met whenever they fall within the EXALTED scope of work.

The EXALTED architecture is based upon derived M2M use cases (different scenarios within Intelligent Transport Systems, Smart Metering & Monitoring and E-Health) and represents the basis for meeting the technical requirements identified by projects objectives (functional, network, service and device requirements).

The adopted architecture covers a wide area of communication scenarios between end-devices and M2M servers, or between end-devices through the LTE-M access network, with the main objective being to provide an architecture which supports efficient and cost-effective wireless M2M communications

The EXALTED architecture consists of two elements, namely components and interfaces. Components can be either physical entities, e.g. devices, or the logical combination of functions, e.g. EPC and M2M server. All components are characterized by their functionality, which can be either mandatory or optional. Algorithms realizing these functions are considered to be exchangeable and not part of the architecture. In the style of [2], it is distinguished between device domain (DD) and network domain (ND). The paper provides a summary of all relevant components and their functionality as far as considered in EXALTED

The interaction between components is controlled by interfaces. They can be grouped in two main categories, namely peer-to-peer lower layer interfaces and end-to-end higher layer interfaces. The purpose of an interface is to support appropriate signalling exchange on the respective layers between the components at both of its ends in order to provide the related services. Interfaces are realized by protocols. Apart from IP, which is one the basic working assumptions in EXALTED, it is left to individual project technical workpackages to define how the protocols are specified.

The EXALTED architecture will serve as the basis for introduction of innovative functionalities enabled by the Gateway [7] (protocol translation, address translation etc), innovative functionalities enabled within the capillary network [8] (new MAC design and clustering techniques etc), new Device management functionalities [9] (OMA-DM v1.x compliant Lightweight Device Management solution, Device Management over CoAP, Lightweight monitoring etc), advanced Low cost security solutions (Low overhead Security, Embedded SIM, Sharing Elements etc) as well as for various innovations in LTE-M access network [10] (LTE-M algorithms).

References

[1] 3GPP TR 23.888 V1.6.1, "System Improvements for Machine-Type Communications," Release 11, February, 2012.
[2] ETSI TS 102 690 V1.1.1, "Machine-to-Machine communications (M2M); Functional architecture," October, 2011.
[3] FP7 EXALTED consortium, "D3.3 – Final report on LTE-M algorithms and procedures", project report, July 2012.
[4] 3GPP TS 23.002: "Network Architecture".
[5] 3GPP TS 23.401: "GPRS enhancements for E-UTRAN access".
[6] 3GPP TS 23.402 "Architecture enhancements for non-3GPP accesses".
[7] FP7 EXALTED: "D4.2 - IP Networking System for M2M communications for EXALTED use cases", project report, June 2012.
[8] FP7 EXALTED: "D4.1 - M2M Packet Data Protocols between LTE-M and Capillary Networks", project report, June 2012
[9] FP7 EXALTED: "D4.3 – Device Management", project report, October 2012.
[10] FP7 EXALTED consortium, "D3.3 – Final report on LTE-M algorithms and procedures", project report, July 2012.

Sadržaj: *Razvoj machine-to-machine (M2M) tehnologije i komunikacionih standarda obezbeđuje interoperabilnost M2M uređaja i mreža, smanjenje troškova proizvodnje i veće M2M tržište. Ovaj rad se fokusira na sistem arhitekturu koja se razvija unutar EXALTED projekta (EXpAnding LTE for Devices). EXALTED je EU FP7 projekat koji za cilj ima kreiranje standarda za M2M komunikaciju preko LTE mreže. U radu biće predstavljena EXALTED sistem arhitektura sa kratkim osvrtom na ETSI i 3GPP M2M standarde, a posebno će biti naglašeno mapiranje EXALTED arhitekture u ETSI i 3GPP okvire. Interakcija između različitih M2M domena (network i device domeni) će takođe biti prezentovana.*

Keywords: *machine-to-machine (M2M), M2M arhitektura, EXALTED sistem*

EXALTED SISTEM ARHITEKTURA

Aleksandar Obradović, Nenad Gligorić