M2M Core Networks
物聯網核心網路

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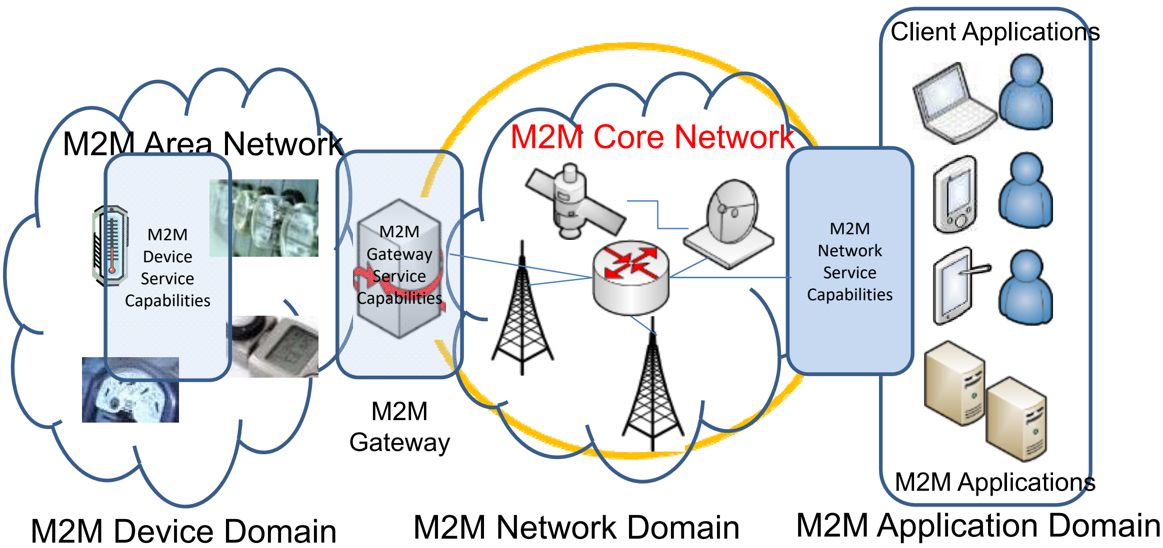


Outline

1. M2M Impact to Core Networks
2. Core Network Optimization for M2M
3. Impact of Low Power Wide Area Network (LPWAN)

M2M Impact to Core Networks

M2M Impact to Core Networks
Outline

- M2M Communication Scenarios
- Which Network to Use: Fixed or Mobile?
- Characteristics of M2M Communications
- Impact to Core Networks
  1. Cost Reduction Requirement
  2. Value-Added Services Requirement
  3. Numbering, Identifiers, and Addressing Requirement

M2M Communication Scenarios

- Network Communication Scenarios
  - Machine-to-machine
  - Machine-to-server
  - Machine-to-gateway-to-server
- Machine Communication Scenarios
  - Rarely send data and device-originated only
  - Rarely send data but have to be reachable
  - Continuously need to send and receive data
  - Occasionally need to send data
  - High-bandwidth data such as video surveillance
  - Low-bandwidth data such as meter reading

Which Network to Use: Fixed or Mobile?

- Mobile network is the choice because
  - The cost of connecting M2M devices to a fixed network (wiring and cabling to each device) could be very expensive.
  - A large percentage of M2M applications involves mobile devices (e.g. connected car, eHealth)
  - Global roaming can be supported by the mobile network.
- However, need to ensure the ubiquitous coverage of a mobile network.

Characteristics of M2M Communications

- M2M communications can be characterized by their
  - Data Volume,
  - QoS Requirements,
  - Time Sensitivity and
  - Communication Direction.
- The network needs to be designed to deal with device/application diversities.

Impact to Core Networks (1)

Cost Reduction Requirement

- M2M communications have to be low-cost (per device). Thus the cost to provide M2M communications by operators has to be reduced to a minimum.
- To meet this requirement, we need to first understand cost drivers and network cost components of M2M communications.

Cost Reduction Requirement

Cost Drivers and Network Cost Components

- Cost Drivers
  - Number of group-based subscriptions
  - Number of simultaneously attached devices
  - Number of simultaneous always on data connections
  - Number of data sessions
  - Volume of data throughput
- Network Cost Components
  - SIM cards; E.164 numbers; HLR capacity
  - Mobility context data in network node
  - Session context data in network node
  - Signaling for mobility management and connection setup
  - Radius/Diameter capacity
  - Radio capacity etc.

Cost Reduction Methods

- Group-based Communications
- Network Resource Reduction for Idle Devices
- Network Signaling Reduction
- Avoidance of Peaks in User Data
- Separate Network for M2M

Group-Based Communications

- Types of Group-Based Communications
  - Group-based subscription and charging
  - Group-based policing
  - Group-based triggering
- Issues of Grouping M2M Devices
  - Allowing devices belong to multiple groups complicates subscription and profile management.
  - 3GPP allows only one group for each subscription.

Network Resource Reduction for Idle Devices

- Devices that are idle but attached to the network still keep their session context or mobility management context.
- Trade-off between
  - saving network resources by removing these device contexts and
  - adding the signaling overhead of reattaching and reconnecting these devices for sending data.

Network Signaling Reduction

- In M2M communications, the ratio between the amount of network signaling and the amount of use data transmitted is relatively high.
- Ways to reduce network signaling:
  - Charge not only data but signaling of M2M devices.
  - Exchange no mobility management signaling when devices are not moving.
  - Keep devices detached when they have no data to send.
  - Keep devices connected if they frequently send data
  - Send small data along with the signaling message.

Avoidance of Peaks in User Data

- This is for operators to move the data transmission of M2M devices from peak hours of mobile networks by providing lower-rate or other incentives.
- 3GPP proposes the notion of “time-controlled” where an M2M device can only send data during a particular access grant time interval.
- Need to randomize access from M2M devices within the access grant time interval to avoid collision.

Separate Networks for M2M

- Two scenarios
  - Separate both core and access networks for H2H and M2M communications
  - Only separate core networks for M2M communications
- Core networks designed specifically for M2M
  - Dedicated Core Network Central Equipment such as
    - Dedicated HLR: avoid congestion and overload from massive number of devices wanting to register on network at same time
    - Dedicated GGSN: customized for M2M
  - Specific GGSN Access Point Name (APN) for handling M2M traffic

Impact to Core Networks (2)
Value-Added Services Requirement

- The example value-added services that operators must provide for M2M communications
  – QoS and Priority Differentiation
  – Charging and Subscription Management
  – Device Management
  – Connection Monitoring
  – Fraud Control
  – Secure Connection

QoS Differentiation

- QoS for mobile networks should be applicable for serving diverse M2M services
- For example, QCI (QoS Class Identifier) for LTE is defined as follows.

Type	QCI	Priority	Packet delay (ms)	Packet error rate	Service example
GBR	1	2	100	0.01	Voice call (CBR)
	2	4	150	0.001	Video call (CBR)
	3	3	50	0.001	Real time Gaming
	4	5	300	0.000001	Video on demand
Non-GBR	5	1	100	0.000001	IMS Signaling
	6	6	300	0.000001	Voice/video over IP, Chat, DL Video streaming, Internet, E-mail etc.
	7	7	100	0.001	
	8	8	300	0.000001	
	9	9	300	0.000001	

Priority Differentiation

- Another differentiation control In LTE is ARP, standing for "Allocation and Retention Priority".
- ARP is used during two procedures: during admission or allocation (setup signaling) of the bearer and during lifetime of the bearer, when new bearer is to be admitted/allocated (The existing bearer may be deallocated to make space for new bearer).
- Also at handover, ARP may be applied to decide which bearer can be dropped from the bearers allocated to a UE.
- ARP has three sub-parameters: priority level (1 thru 15), preemption capability (capable to preempt/not capable to preempt), and preemption vulnerability (preemptable /not preemptable).

Charging and Subscription Management

- What operators need to provide include:
  - Customer management for group charging and subscription
  - Flexibility for device subscription and management by M2M application owners (no provisioning until the device is purchased)
  - Remote management of SIM cards (e.g. over-the-air provisioning with subscription details)
  - Flexible choices of mobile operators by customers

Device Management (New!)

- Operators can provide values by
  - Initial activation of M2M devices
  - Continuous remote management of M2M devices
  - Support of device management protocols defined in OMA (Open Mobile Alliance) DM (Device Management) and BBF (Broadband Forum) TR-069.

Connection Monitoring (New!)

- Need to ensure device connectivity is always in good condition.
- How to detect any anomaly without producing too much signaling overhead is a challenge.
- Connectivity status may include loss of connectivity, removal of a SIM card, roaming outside a particular area, or potential fraud etc.
- The events can be reported to M2M applications for appropriate actions.

Fraud Control

- Detection of fraud can be an important value-added service by mobile operators. Examples for detection:
  - A device suddenly transmits more data than usual.
  - A device changes its location unexpectedly.
  - Etc.
- Prevention of fraud potentially include
  - Restrict the validity of SIM with certain types of device.
  - Restrict the connectivity of devices to limited addresses.
  - Restrict the functioning of devices to specific locations
  - Etc.

Secure Connection

- Mobile operators support data transport security over mobile networks such as encryption for data transmitted over the radio interface and IP VPN for the interface between M2M gateway and server.
- In addition, operators also need to support end-to-end security for M2M applications at the application level.

Impact to Core Networks (3)

Numbering, Identifiers, and Addressing Requirement

- E.164 Numbers
- IMSI Identifiers
- IMEI Identifiers
- ICCID Identifiers
- IP Addresses

E.164 (or MSISDN) Numbers

National Significant Number

CC	NDC	SN

CC – Country Code
NDC – National Destination Number
SN – Subscriber Number

1-3 digits
International Subscriber Number
15 digits

- In M2M communications where majority of communications is data, a telephone number is not needed strictly.
- Nevertheless, an E.164 number is needed for billing, provisioning and for over-the-air device and SIM management in mobile networks.
- Thus there is an urgent shortage of numbers for M2M unless alternatives are developed for E.164.
- Options available include
  - IMSI and IP address
  - Fully Qualified Domain Name (FQDN).
  - SIP URI

IMSI Identifiers

MCC	MNC	MSIN
3 digits	2-3 digits	9-10 digits

MCC –Mobile Country Code
MNC – Mobile Network Code
MSIN – Mobile Subscription identification Number

- IMSI (International Mobile Station Identifier) is used in mobile networks to identify a particular subscription.
- 9 digits for MSIN can only support up to 10 million subscriptions.
- So it is best to have 10 digits for MSIN (up to 100 million subscriptions)
- If still not sufficient, an operator may need to take more than one MNC codes.
- IMSI thus is under stretch.

IMEI Identifiers

TAC	SNR	CD
8 digits	6 digits	1 digit

TAC –Type Allocation Code
SNR – Serial Number
CD – Check Digit/Spare Digit

TAC	SNR	SVN
8 digits	6 digits	2 digits

TAC –Type Allocation Code
SNR – Serial Number
SVN – Software Version Number

- The IMEI (International Mobile Equipment Identity and Software Version) numbers are used to identify individual mobile devices.
- TAC identifies a particular model of mobile device.
- However, with 6-digit SNR the maximum number of devices of a single type Is only 1 million.
- To escape this limit, multiple TACs may be allocated to the same type of devices.

ICCID Identifiers

Issuer Identification Number
4-7 Digits

Major Industry Identifier	Country Code	Issuer Identifier Number	Individual Account Identification Number	Check Digit
2 digits	1-3 digits	1-4 digits	12-15 digits	1 digit

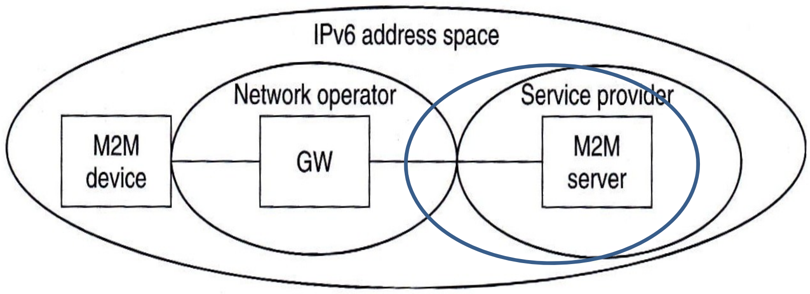
Integrated Circuit Card Identifier (19 digits)

- The ICCID (International Circuit Card Identifier) identifies individual UICCs (Universal Identify Chip Cards).
- There are at least 12 digits for every issuer identification number. This is adequate for M2M applications.

IP Addresses

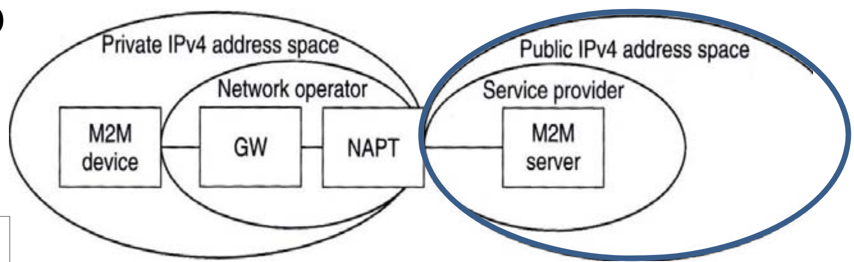
- IPv6 Scenario

(V) Device->Server
(V) Server->Device



- IPv4 Scenario

(V) Device->Server
(X) Server->Device



V: OK
X: Special solution required

Source: M2M Communications: A Systems Approach, Wiley, 2012

Core Network Optimization for M2M

Core Network Optimization for M2M

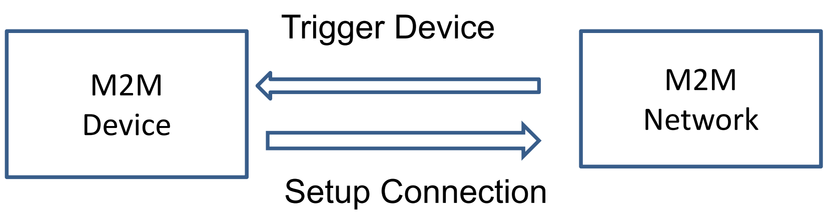
- Triggering Optimization
- Overload and Congestion Control
- 3GPP Standardization

Triggering Optimization Outline

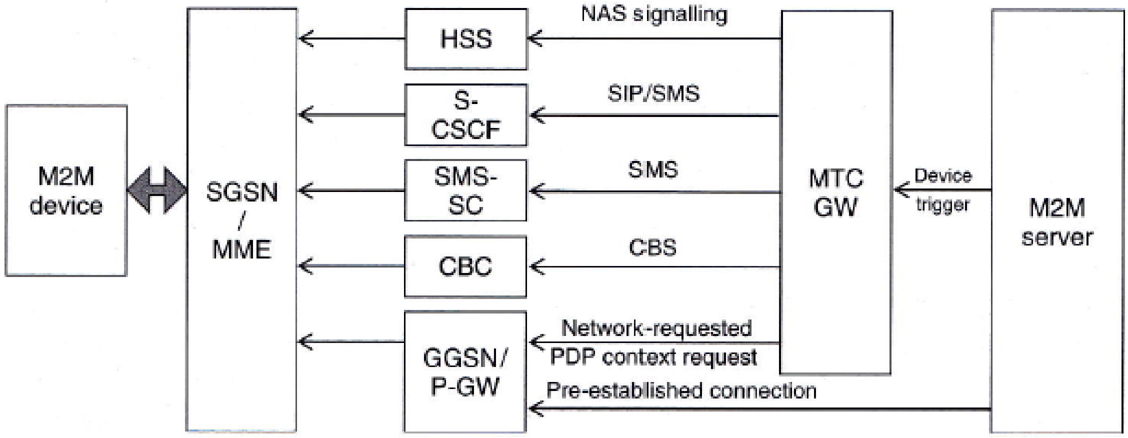
- What is triggering?
- Triggering mechanisms defined by 3GPP 23.888
  - Triggering using Mobile-Terminated SMS
  - Triggering using IMS message
  - Triggering using cell broadcast (CBS)
  - Triggering via HSS and non-access stratum (NAS) signaling
  - Triggering via network-requested PDP context establishment

What Is Triggering?

- To enable network-originated communications while the network only supports device-originate communications



Triggering Mechanisms Defined by 3GPP



Source: M2M Communications: A Systems Approach, Wiley, 2012

3GPP defines a machine-type communication gateway (MTC GW) that will act as an entry point in the mobile network for control messages from M2M servers to M2M devices.

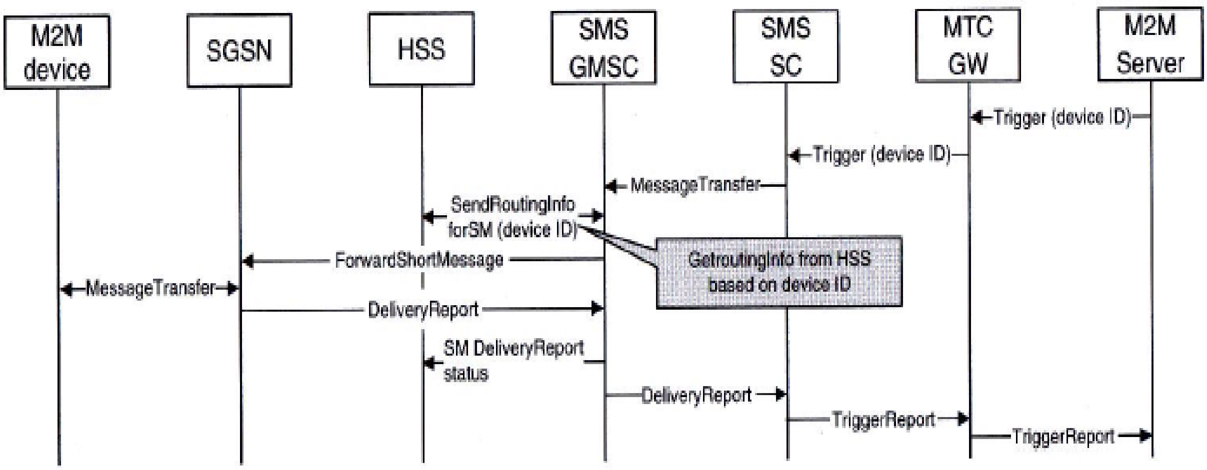
Status of Devices When Being Triggered

- The devices can be
  - Connected with IP Address known to the server
  - Connected without IP Address known to the server
  - Attached but not connected
  - Unattached (unreachable)
- Each requires different methods of triggering.

Information in Triggering Message

- The identify of the target M2M device
- The identity of the application
- A request counter
- (option) IP address (or FQDN)/port number of application server
- (option) An urgency indicator
- (option) A validity timer
- (option) The target area
- (option) Application-specific information

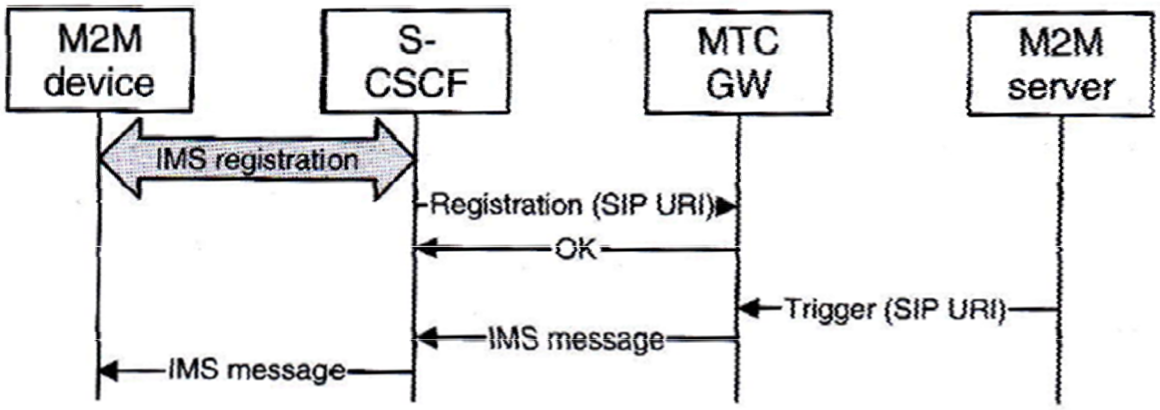
Triggering using Mobile-Terminated SMS



Source: M2M Communications: A Systems Approach, Wiley, 2012

- The M2M device identify can be an IMSI or an MSISDN replacement.
- But security is a major concern.

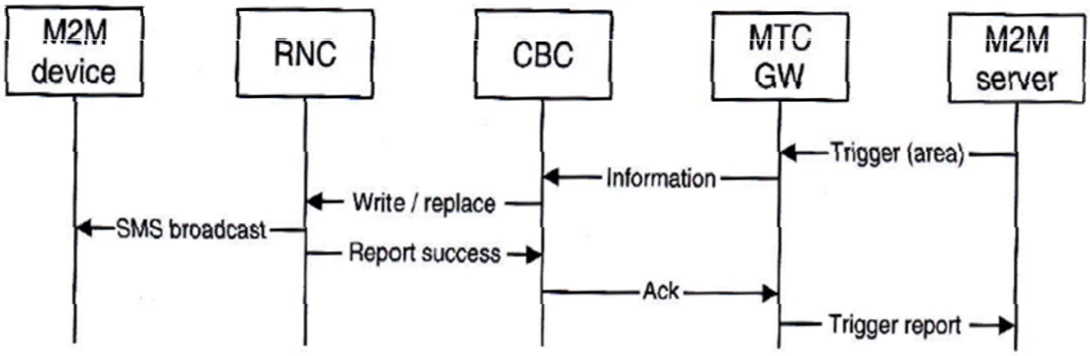
Triggering using IMS Message



Source: M2M Communications: A Systems Approach, Wiley, 2012

- The MTC GW is viewed as an IMS Application Server.
- But an M2M device has to maintain an IMS session which is too heavy for M2M communications.

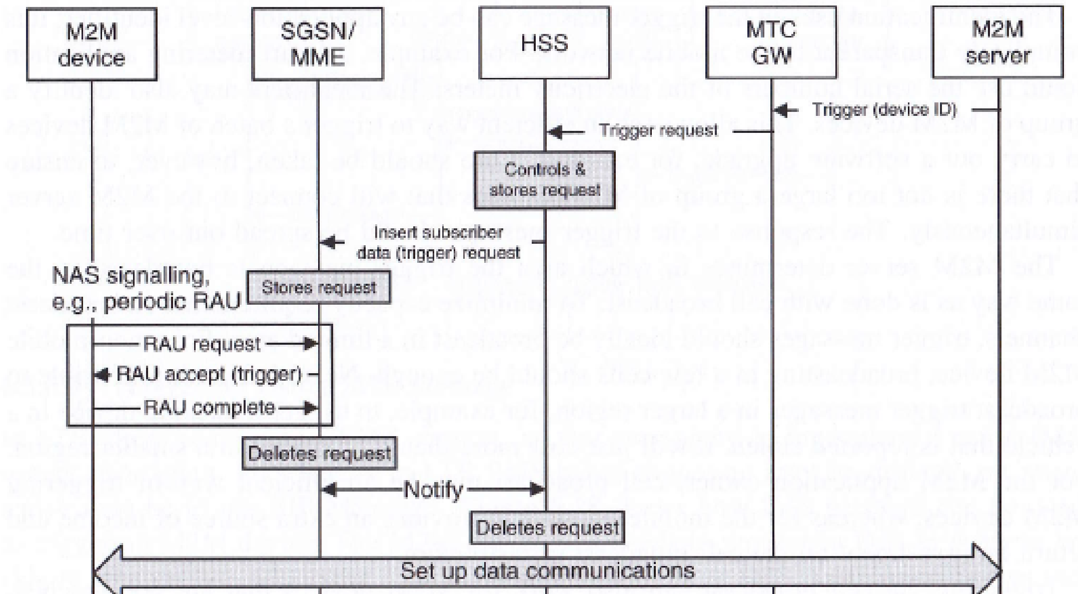
Triggering using Cell Broadcast



Source: M2M Communications: A Systems Approach, Wiley, 2012

- The M2M Server uses Cell Broadcast Center (CBC) to broadcast the trigger message within an indicated area.
- The M2M device matched the identification will respond.

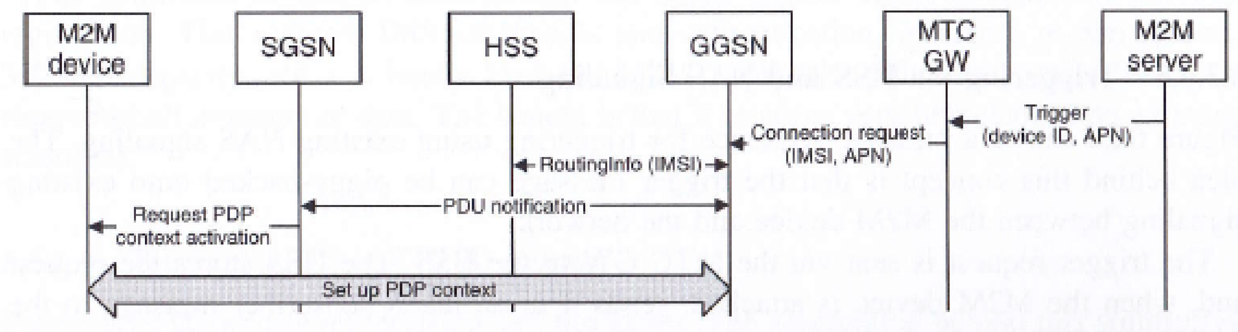
Triggering via HSS and Non-Access Stratum (NAS) Signaling



Source: M2M Communications: A Systems Approach, Wiley, 2012

The triggering message is piggybacked on RAU (Routing Area Update) Accept message.

Triggering via Network-Requested PDP Context Establishment



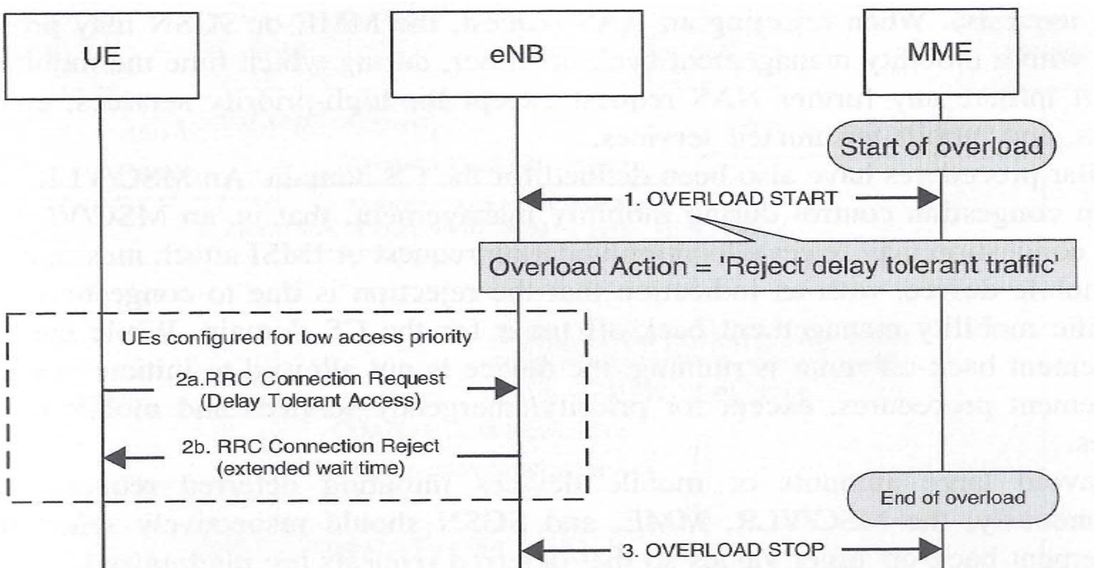
Source: M2M Communications: A Systems Approach, Wiley, 2012

- Use IMSI as the device ID in the network
- Use network-requested PDP (Packet Data Protocol) context establish to trigger the device.

Overload and Congestion Control

- Network Overload Control for Mobile Devices Configured with “Low-Access Priority”
- Generic Mobility Management Congestion Control for Core Network
- Selective Throttling of Downlink Low-Priority Traffic Received for M2M Devices in idle Mode
- Application-Specific Congestion Control
- Optimization to Prevent Overload from Network Reselection
- Extended Access Barring

Network Overload Control for Mobile Devices Configured with “Low-Access Priority”



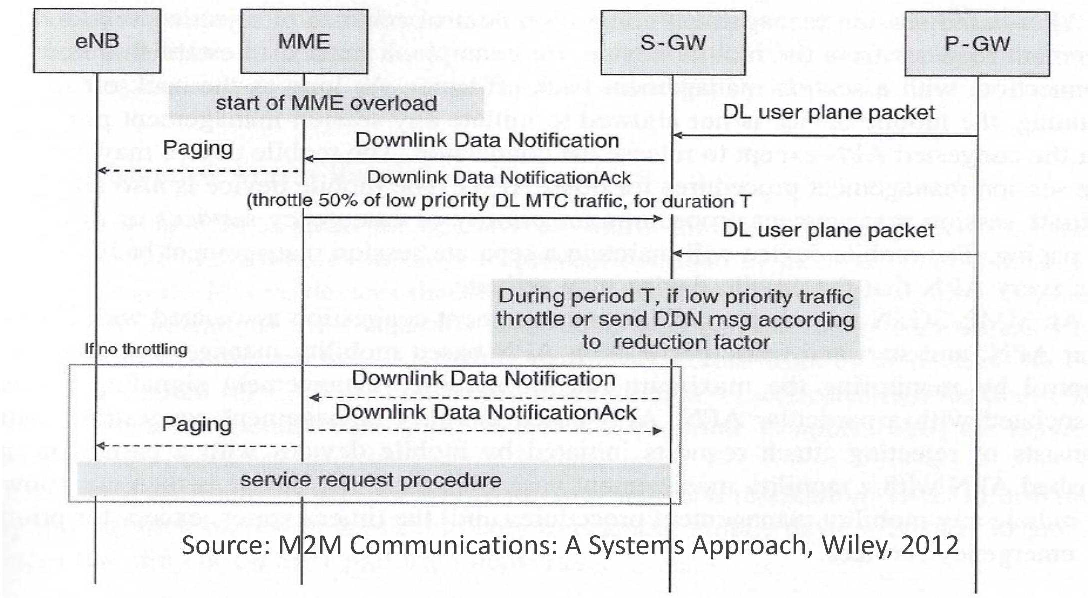
Source: M2M Communications: A Systems Approach, Wiley, 2012

To control the impact of M2M communications, M2M devices can be configured with “Low-Access Priority”

Generic Mobility Management Congestion Control for Core Network

- An MME (or SGSN) may reject mobility management (i.e. Non-Access Stratum (NAS)) signaling from M2M devices (i.e. attach, tracking area update or routing area update request etc.)
- When rejecting such requests, the MME will provide M2M devices with a mobility management back-off timer to avoid collision of re-attempts.

Selective Throttling of Downlink Low-Priority Traffic Received for M2M Devices in idle Mode



Source: M2M Communications: A Systems Approach, Wiley, 2012

MME can ask S-GW to throttle downlink low-priority traffic for a time period T according to a reduction factor.

Application-Specific Congestion Control

- Deal with signaling congestion associated with a particular APN (Access Point Name).
- The APN in LTE/EPC identifies a Packet Data Network Gateway (P-GW) and defines the Packet Data Network (PDN) to which the UE requests connectivity.
- Using APNs, traffic from M2M applications can be identified.
- When congestion occurs, M2M traffic then can be rejected based on particular APNs.

Optimization to Prevent Overload from Network Reselection

- When searching for a network fails, all M2M devices in the same network may simultaneously reselect an alternative network for connectivity. This causes overload to the alternative network.
- Need to carefully select the timer so that the search for network won’t expire too early to attempt a reselection.

Extended Access Barring

- A process to allow the operator to control M2M device-originated access attempts.
- This may be useful also in preventing overload from network re-selection.
- EAB may be applicable only to roaming mobile devices or devices not in their preferred networks.

Network Optimization for MTC – 3GPP Standardization

- 3GPP WG SA1 established a work item on network improvement for machine type communications (MTC) in 2008.
- Samples of 3GPP documents addressing impact of MTC
  - TS 22.368, " Service Requirements for MTC"
  - TS 22.888, "Study on Enhancements for MTC"
  - **TR 23.888, "System Improvements in MTC"**
  - TS 23.682, "Architecture Enhancements to Facilitate Communications with Packet Data Networks and Applications"
  - TS 33.868, "Security Aspects of Machine-Type Communications"
  - TS 23.401 & TS 22.011 on Core Network Optimization
  - TS 22.011 on Access Network Optimization
  - Etc.

Network Optimization Features for MTC in 3GPP Releases 10 and 11

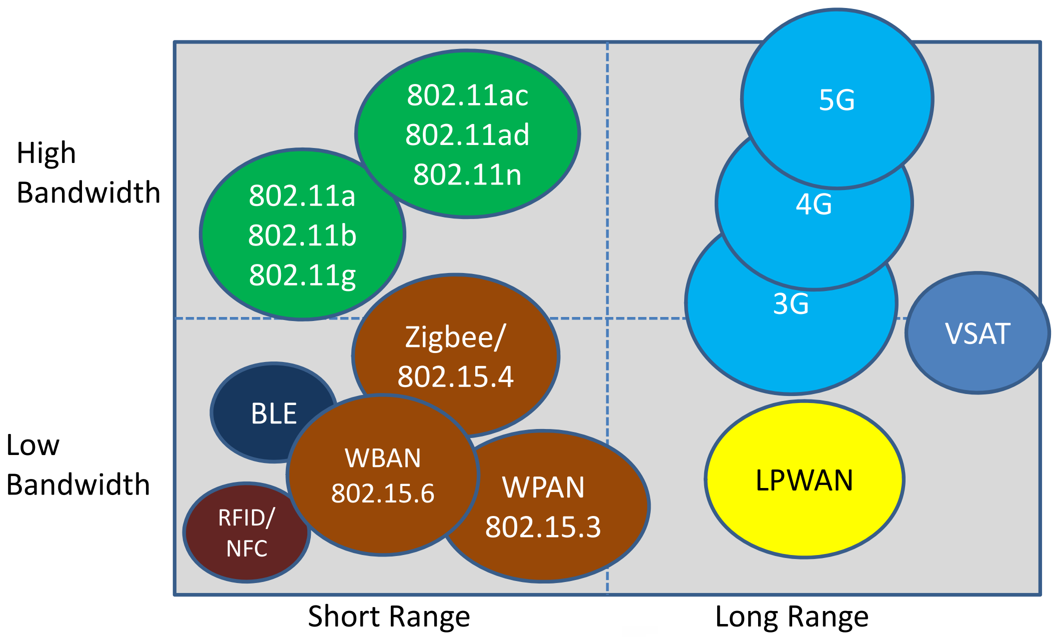
- Release 10
  - Extended access barring
  - Low-access priority indicators in radio-resource control
  - Extended wait timers in radio resource control
  - Throttling of downlink data notification requests
  - APN-based congestion control
  - Generic core network mobility management control
  - Optimizations to prevent overload from PLMN reselection
- Release 11
  - Triggering optimization and triggering architecture
  - Addressing optimizations and removal of dependency on telephone numbers

Impact of Low Power Wide Area Network (LPWAN)

Low Power Wide Area Network (LPWAN)

- Non 3GPP Unlicensed Networks (already deployed)
  - E.g. LoRaWAN, Sigfox, Neul and Nwave (based on Weightless–N) etc.
  - Most of these networks take advantage of ISM (industrial, scientific, and medical) unlicensed frequency bands.
- 3GPP Licensed Networks Evolution (released in 3GPP Rel. 13; under development)
  - eMTC – LTE-M (M: MTC - machine type communication) evolution
  - NB-IoT (evolved from NB-CIoT and NB-LTE)
  - EC-GSM

Importance of LPWAN



Non 3GPP LPWAN

LoRaWAN (1)

- Target key requirements of Internet of things such as secure bi-directional communication, mobility and localization services.
- Typically laid out in a star-of-stars topology in which gateways is a transparent bridge relaying messages between end-devices and a central network server in the backend.
- All end-point communication is generally bi-directional, but also supports operations such as multicast, enabling software upgrade over the air or other mass distribution messages to reduce the on-air communication time.
- Communication between end-devices and gateways is spread out on different frequency channels and data rates. Data rates range **from 0.3 kbps to 50 kbps**. The LoRaWAN network server is managing the data rate and RF output for each end-device individually by means of an **adaptive data rate (ADR)** scheme.

Source: LoRa Website

LoRaWAN (2)

- Secure communications by several layer of encryption: Unique Network key (EUI64) on network level, Unique Application key (EUI64) for end to end security on application level and Device specific key (EUI128).
- Support three classes of end-point devices:
  - **Bi-directional end-devices (Class A):** Devices require downlink communication from the server shortly after the end-device has sent an uplink transmission.
  - **Bi-directional end-devices with scheduled receive slots (Class B)**: In addition to the Class A random receive windows, Class B devices open extra receive windows at scheduled times.
  - **Bi-directional end-devices with maximal receive slots (Class C):** End-devices of Class C have nearly continuously open receive windows.

Source: LoRa Website

SIGFOX

- SIGFOX provides a tailor-made solution for low-throughput IoT/M2M applications.
- Designed for IoT/M2M devices characterized by:
  - Up to 140 messages per device per day
  - Payload size for each message is **12 bytes**
  - Wireless throughput up to **100 bits per second**
- Based on Ultra-Narrow Band (UNB) technology such as unlicensed ISM radio bands (in Europe, 868MHz; in the US, 915MHz)
- Cellular scope at an average range of about **30-50km** in rural areas and in urban areas **between 3 and 10km**.
- Deployment in Netherlands, France, the UK, Spain and San Francisco in the US.

Neul

- Neul provides a highly-scalable ubiquitous wide area wireless connectivity solution, providing deep indoor coverage, **10-15 year battery life** at low cost and the ubiquity of security without awkward configuration.
- Based on Weightless-N (based on ISM bands), also a UNB technology.
- Deployed and trialed in Milton Keynes of the UK.
- Acquired by Huawei on September 22, 2014 at $25M.

Nwave (1)

- Nwave employs advanced de-modulation techniques to its network to co-exist within the ISM bands with other radio technologies without the risk of collisions and capacity problems.
- Unlike some other IoT communications technologies that require the use of a mesh network, UNB is highly scalable, allowing for high capacity networks with a **simple star architecture**, whereby devices communicate directly with base station transceivers.
- Nwave ensures that data sent over its networks are secure, so its platform is suitable for use in applications where data privacy and security are critical.

Source: Nwave Website

Nwave (2)

- Nwave technology operates a Weightless-N Smart City network in London.
- Operating in sub-1GHz, license-exempt ISM spectrum using ultra narrow band (UNB) technology, Weightless-N offers best-in-class signal propagation characteristics, leading to **excellent range of several kilometers**, even in challenging urban environments such as the city of London.
- Very low power consumption provides end points with **exceptionally long battery life measured in years** from small conventional cells.
- Both terminal hardware and network costs are also minimized with leading edge design.

Source: Nwave Website

Comparion among LoRaWAN, NWave, Neul and Sigfox

	LoRa	NWave	Neul	Sigfox
Architecture & Topology	Star-of-stars topology	Star Topology	Star Topology	Star Topology
Wireless Technologies *Adaptive Data Rate	Spread spectrum, ADR* 0.3-50kbps, ISM band, point-to-point and multicast	UNB, Nwave software-defined radio, in sub-GHz license-exempt spectrum	ISM band (868/902MHz), TV white space, or licensed sub-GHz	UNB, ISM band, payload 12 bytes, up to 100 bps, Sigfox protocol
Base Station Functionality	3~8/15~45 Km, 1M nodes	10~30 Km, 1M nodes	NeulNET, 10 Km	3~10/ 30 ~50Km/1Mn
BS and Device Cost	B $4980 Euros 3 class devices	D < $8	D (Iceni) $4	B 3000 Euros D < US$3
Security Support	Network/ application/ device keys	NWave security	AES	AES
Backend Support	Backend server	Backend server	Data cloud (NaaS), billing, DM, OSS/BSS	Sigfox OSS/BSS
Applications	Healthcare, Tracker, agriculture, lighting	Smart parking, smart meter, smart agriculture	Waste mgmt., Pest control, wind energy	Car theft detector, water meter, valve control
Standards	LoRaWAN	Weightless-N, 30k~100k bps	Weightless-N, -W, -P (P: 16Mbps)	
Deployment Field	USA, France, Netherlands	London, UK	Smart city - Milton Keynes, UK	Netherlands, France, UK, Spain and USA

3GPP LPWAN

LTE-M

- A study for low-cost LTE is on-going in 3GPP since September 2011. Release 12 has specified LTE Cat0 (LTE-M) and Release 13 evolves to eMTC.
- Main goal of the study is to reduce cost of LTE devices to be utilized for M2M.

  Identified approaches include:
  - Reduction of Bandwidth
  - Hardware simplification
  - Reduction of Transmit Power
  - Reduction of Peak Rate

Source: 3GPP

LTE-M for 3GPP Rel. 12

- Antennas
  - Only 1 receive antenna compared to 2 antennas for other device categories
- Transport block size
  - Send or receive up to **1000 bits** of unicast data per sub-frame
  - Reduce the max data rate to **1 Mbps** in both the uplink and the downlink
- Duplex
  - Half duplex FDD devices are supported as an optional feature

Source: 3GPP

eMTC for 3GPP Rel. 13

Objectives

- Long battery life: ~10 years of operation with 5 Watt Hour battery
- Low device cost: comparable to that of GPRS/GSM devices
- Extended coverage: >155.7 dB maximum coupling loss (MCL)
- Variable rates: ~10 kbps to 1 Mbps depending on coverage needs

Deployment

- Can be deployed in any LTE spectrum
- Coexist with other LTE services within the same bandwidth
- Support FDD, TDD and half duplex (HD) modes
- Reuse existing LTE base stations with software update

Source: 3GPP

eMTC for 3GPP Rel. 13 (Cont.)

Main PHY/RF Features

- Narrowband operation with 1.08 MHz bandwidth
- Frequency hopping with narrowband retuning for frequency diversity
- TTI bundling/repetition to achieve large coverage enhancements
- New UE power class of 20 dBm
- Further cost reduction beyond Cat 0 (no wideband control channel, reduced TM support, reduced HARQ)

Source: 3GPP

NB-IoT

Objectives

- Even lower cost than eMTC
- Extended coverage: 164 dB maximum coupling loss
- Long battery life: 10 years with 5 Watt Hour battery
- Support for massive number of devices: ~50,000 per cell

Main simplification

- Reduced data rate/bandwidth, mobility support and further protocol optimizations

NB-IoT supports 3 modes of operation:

- **Stand-alone**: utilizing stand-alone carrier, e.g. spectrum currently used by GERAN systems as a replacement of one or more GSM carriers
- **Guard band**: utilizing the unused resource blocks within a LTE carrier's guard-band
- **In-band**: utilizing resource blocks within a normal LTE carrier

Source: 3GPP

NB-IoT (Cont.)

Main PHY features

- Narrow band support of 180 kHz
- Supports two modes for uplink
  - Single tone with 15 kHz and/or 3.75 kHz tone spacing
  - Multiple tone transmissions with 15 kHz tone spacing
- No support of Turbo code for the downlink
- Single transmission mode of SFBC for PBCH, PDSCH, PDCCH
- New narrowband channels:
  - NPSS, NSSS, NPBCH, NPDCCH, NPDSCH, NPUSCH, NPRACH

Main radio protocol Features

- Single HARQ process
- Only RLC AM mode with simplified status reporting
- Two PDCP options:
  - SRB 0 and 1 only. No AS security (NAS security is used instead). PDCP operating in transparent mode.
  - SRB 0, 1, 2 and one DRB. AS security, which is cached upon RRC connection release.
- For PDCP option 2, RRC connection suspend/resume procedures to maintain AS security context.
- Significantly reduced broadcast system information

Source: 3GPP

EC-GSM-IoT

Objectives

- Long battery life: ~10 years of operation with 5 Wh battery
- Low device cost compared to GPRS/GSM devices
- Extended coverage:
  - 164 dB MCL for 33 dBmUE,
  - 154 dB MCL for 23 dBmUE
- Variable rates:
  - GMSK: ~350bps to 70kbps depending on coverage level
  - 8PSK: up to 240 kbps
- Support for massive number of devices: ~50,000 per cell
- Improved security compared to GSM/EDGE

Source: 3GPP

EC-GSM-IoT (Cont.)

- **Main PHY Features**
  - New logical channels designed for extended coverage Repetitions to provide necessary robustness to support up to 164 dB MCL
  - Overlaid CDMA to increase cell capacity (used for EC-PDTCH and EC-PACCH)
- **Other Features**
  - Extended DRX (up to ~52min)
  - Optimized system information (i.e. no inter-RAT support)
  - Relaxed idle mode behavior (e.g. reduced monitoring of neighbor cells)
  - 2G security enhancements (integrity protection, mutual authentication, mandate stronger ciphering algorithms)
  - NAS timer extensions to cater for very low data rate in extended coverage
  - Storing and usage of coverage level in SGSN to avoid unnecessary repetitions over the air

Source: 3GPP

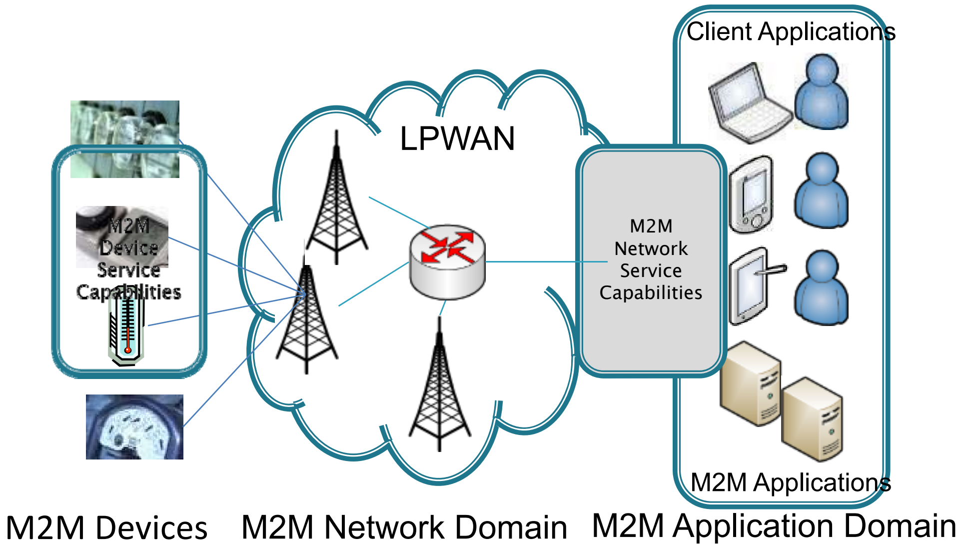
Comparison among eMTC, NB-IoT and EC-GSM-IoT

	eMTC (LTE Cat M1)	NB-IOT	EC-GSM-IoT
Deployment	In-band LTE	In-band & Guard-band LTE, standalone	In-band GSM
Coverage*	155.7 dB	164 dB for standalone, FFS others	164 dB, with 33dBm power class 154 dB, with 23dBm power class
Downlink	OFDMA, 15 KHz tone spacing, Turbo Code, 16 QAM, 1 Rx	OFDMA, 15 KHz tone spacing, TBCC, 1 Rx	TDMA/FDMA, GMSK and 8PSK (optional), 1 Rx
Uplink	SC-FDMA, 15 KHz tone spacing Turbo code, 16 QAM	Single tone, 15 KHz and 3.75 KHz spacing SC-FDMA, 15 KHz tone spacing, Turbo code	TDMA/FDMA, GMSK and 8PSK (optional)
Bandwidth	1.08 MHz	180 KHz	200kHz per channel. Typical system bandwidth of 2.4MHz [smaller bandwidth down to 600 kHz being studied within Rel-13]
Peak rate (DL/UL)	1 Mbps for DL and UL	DL: ~250 kbps UL: ~250 for multi-tone, ~20 kbps for single tone	For DL and UL (using 4 timeslots): ~70 kbps (GMSK), ~240kbps (8PSK)
Duplexing	FD & HD (type B), FDD & TDD	HD (type B), FDD	HD, FDD
Power saving	PSM, ext. I-DRX, C-DRX	PSM, ext. I-DRX, C-DRX	PSM, ext. I-DRX
Power class	23 dBm, 20 dBm	23 dBm, others TBD	33 dBm, 23 dBm

** In terms of MCL target. Targets for different technologies are based on somewhat different link budget assumptions (see TR 36.888/45.820 for more information).*

Source: 3GPP

LPWAN Impact to M2M Core



LPWAN enables IoT devices to connect to backend systems without a gateway!

Summary

- M2M impact to Core Network in
  - Cost Reduction Requirement
  - Value-Added Services Requirement
  - Numbering, Identifiers, and Addressing Requirement
- To best serve M2M, Core Network also requires some new optimization for overload and congestion control.
- LPWAN is emerging as an alternative to the M2M Core.