Chapter 5: Green Wireless Communication via M2M

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Abstract

- Based on the observation that there are a lot more machines, defined as things with mechanical, electrical, or electric properties, than population around the world and the potential added value along with their interconnectivity, machine-to-machine (M2M) communications, allowing interconnectivity of machines, has attracted a large amount of attention over the years.
- The idea of M2M communications is to enable M2M components to be interconnected, networked, and controllable remotely, with low-cost, scalable, and reliable technologies.

Outline

1. Background
2. Green M2M
3. Green M2M application
4. Open research issues

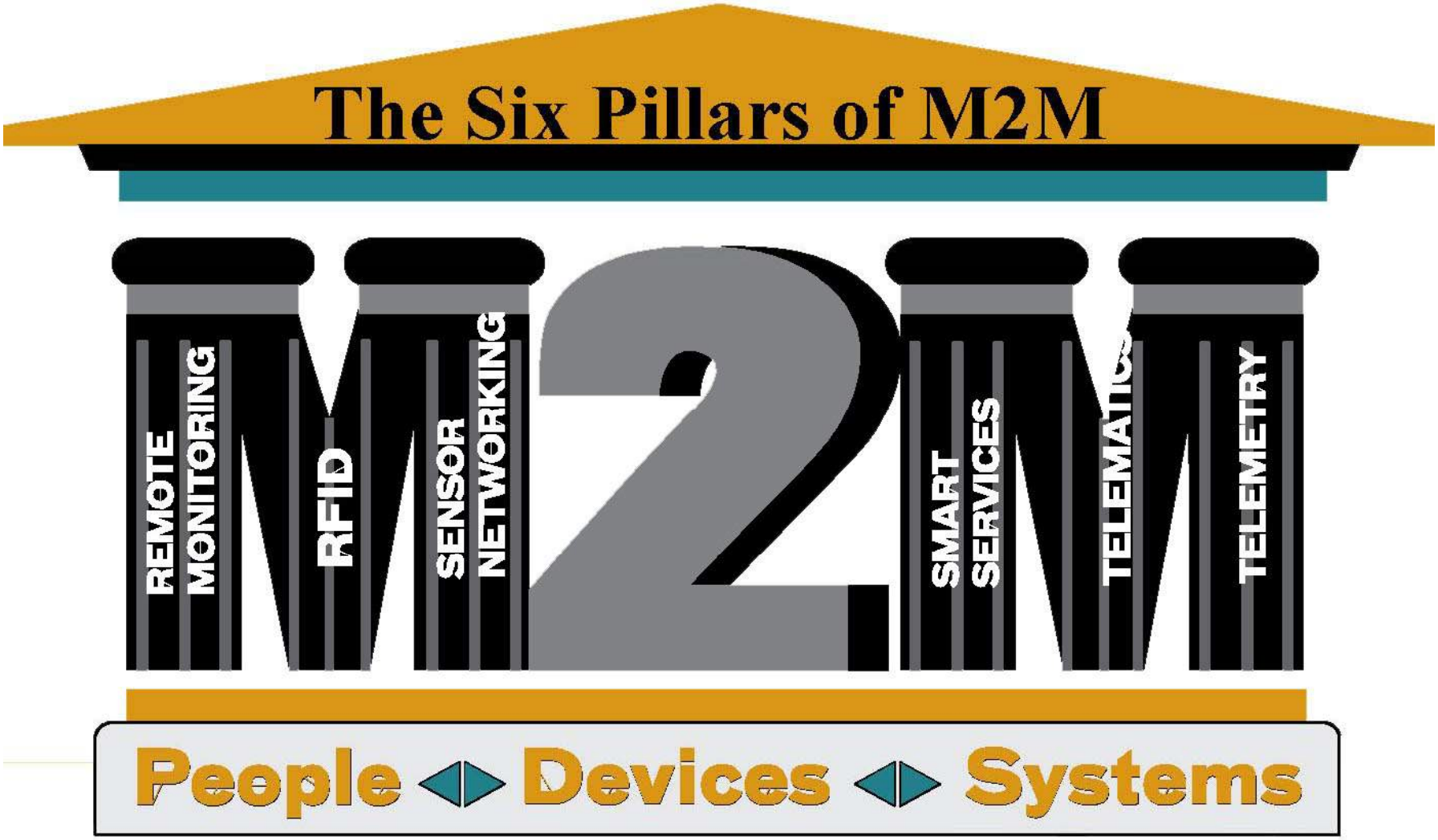
Background

1. Background
   - Overview
   - Machine to machine communication
   - Wireless M2M communications
   - M2M application
2. Green M2M
3. Green M2M application
4. Open research issues

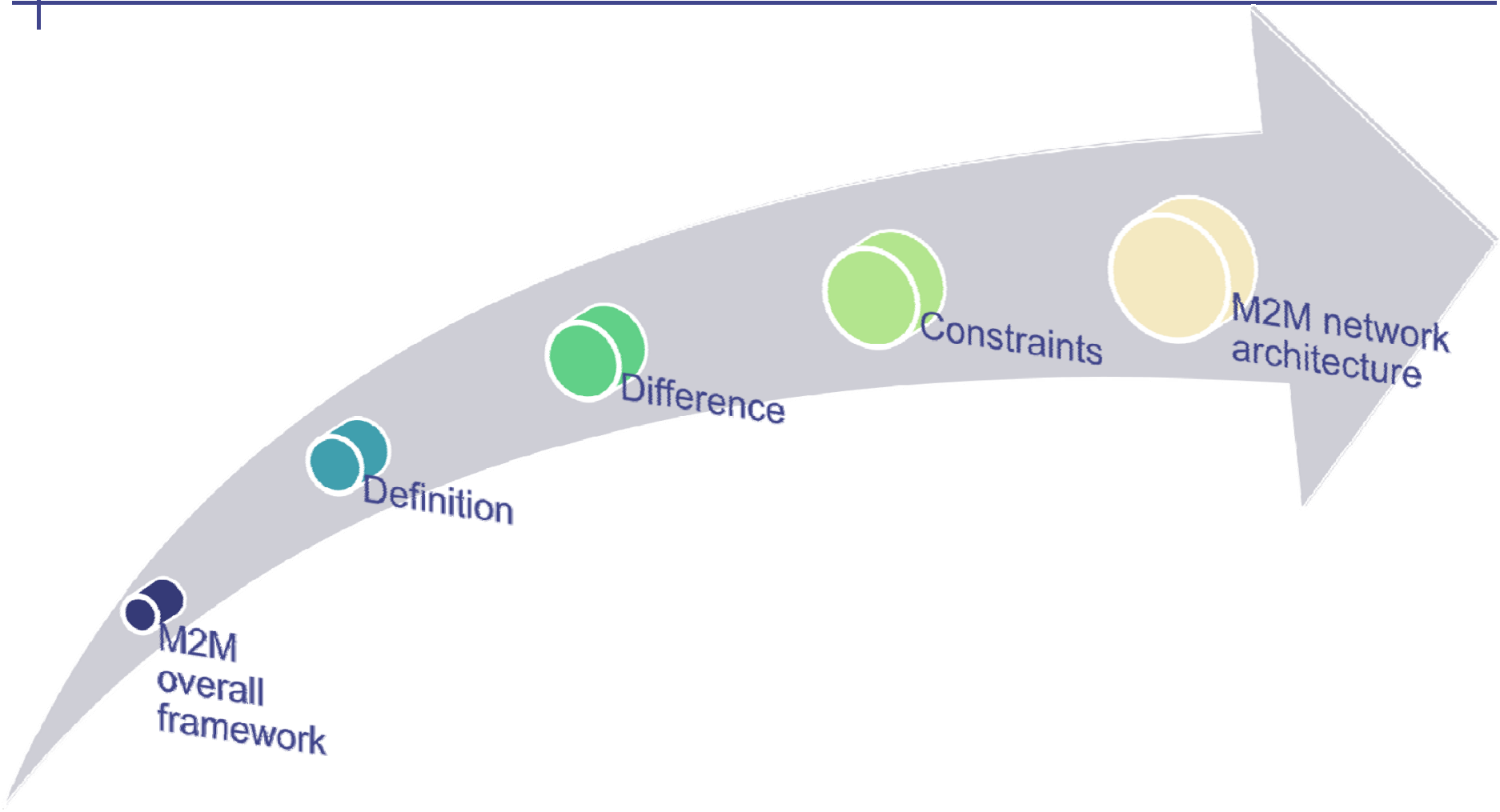
Overview

- The embryonic form of M2M communications end the industrial supervisory control and data acquisition (SCADA) system in the 1980s. In recent years, the topic of M2M communications has attracted much attention from industry the and research community, mainly driven by the following factors:
  - The network infrastructures of these communication systems are already in place, and can be adopted in M2M communications.
  - Advanced software component enables devices to operate intelligently and autonomously. As a result, a number of devices can communicate and perform a variety of functions to achieve the objective of the system.
  - Sensors that can be used to collect information for M2M systems are being widely used and increasingly adopted.

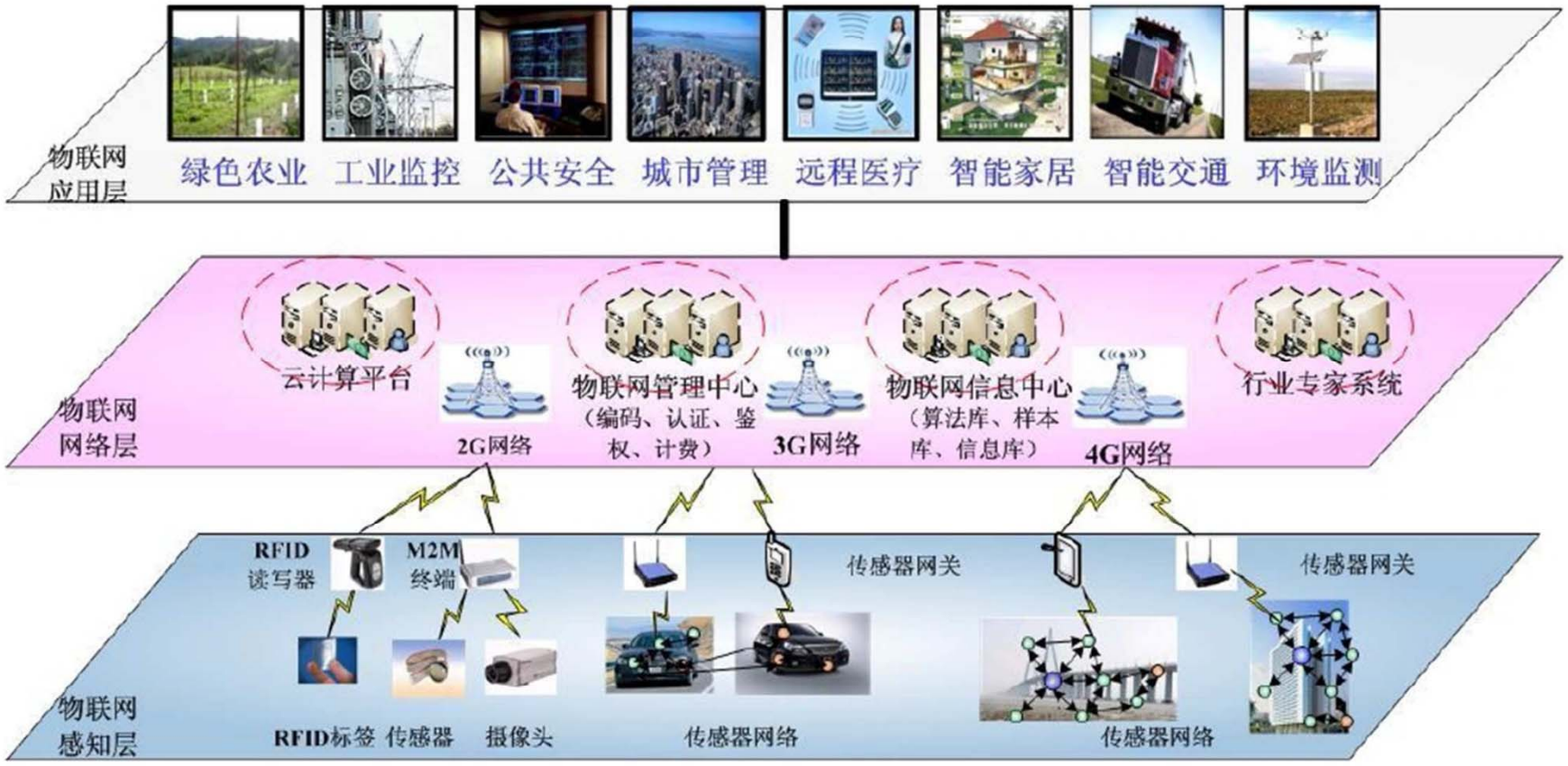
Machine to Machine communication



Machine to Machine Communication

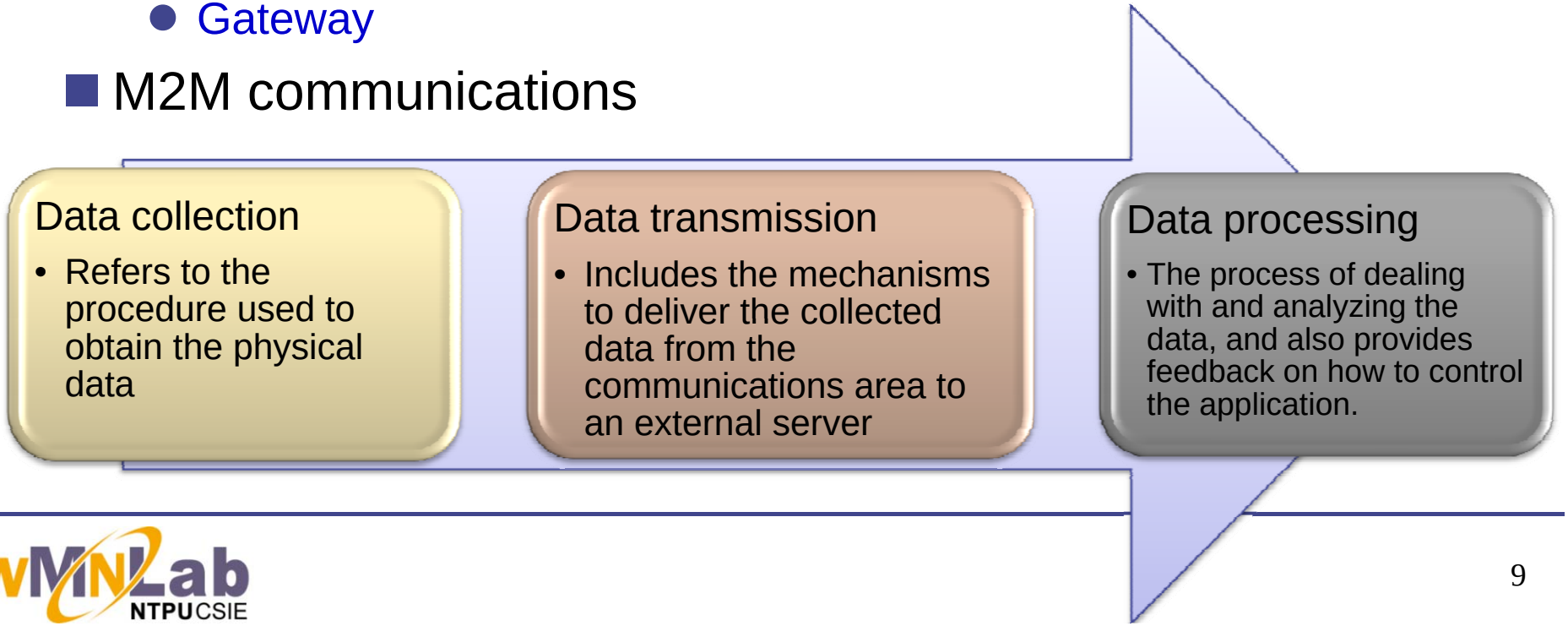


From IoT to M2M



Definition

- Characteristics
  - low power
  - low cost
  - low human intervention
- Composition
  - Networked devices
  - Gateway
- M2M communications



Difference

- Human-to-human communications
  - involve voice calls
  - messaging, web browsing
- M2M communications
  - Increase the level of system automation
    - the devices and systems can exchange and share data.
- The protocol and data format are the major issues in M2M communications to ensure seamless data and control flows

Constraints

- Machines are normally small and inexpensive, which puts several constraints in M2M communications
  - Energy
  - Computation
  - Storage
  - Bandwidth
- These constraints pose a number of unique challenges in the design of M2M networks
  - Highly connected
  - Efficiency
  - Reliability

Constraints (cont.)

- Interference:
  - There is ever more intensive interference with more radio systems, including unlicensed systems operating in the industrial, scientific, and medical (ISM) frequency band, electronic equipment, and domestic appliances. The performance of M2M communications may be seriously degraded due to such self-existence/ coexistence interference.
- Channel dynamics:
  - Wireless channels in M2M communications are notoriously unreliable due to channel fluctuations and noise, which may become even worse due to the complicated construction in an indoor environment.

Constraints (cont.)

- Resource constraints:
  - The machines may be extremely resource constrained with respect to computation, storage, bandwidth, and power supply. There is always an essential trade-off between energy, reliability, and flexibility due to resource constraints
- Devices heterogeneity:
  - A home network generally comprises a large number of different devices as well as distinct services, which may generate dramatically diverse data sources.
- Self-organization:
  - Low human intervention is a major property of home M2M communications. This requires self-capability, including self-organization, self-configuration, self-management, and self-healing.

Constraints (cont.)

- Quality of service (QoS) support:
  - One typical example that requires QoS provision in the M2M communications is a biomedical sensor network. It is extremely important that life critical medical data is reliably delivered before being dropped due to the limited memory of most devices.
- Security:
  - M2M communications are typically required to be inexpensive and preferably unattended, which may expose them to a number of potential attacks. These could be physical attacks, compromise of credentials, configuration attacks, and core network attacks [2].

M2M Network Architecture-ETSI

The device domain

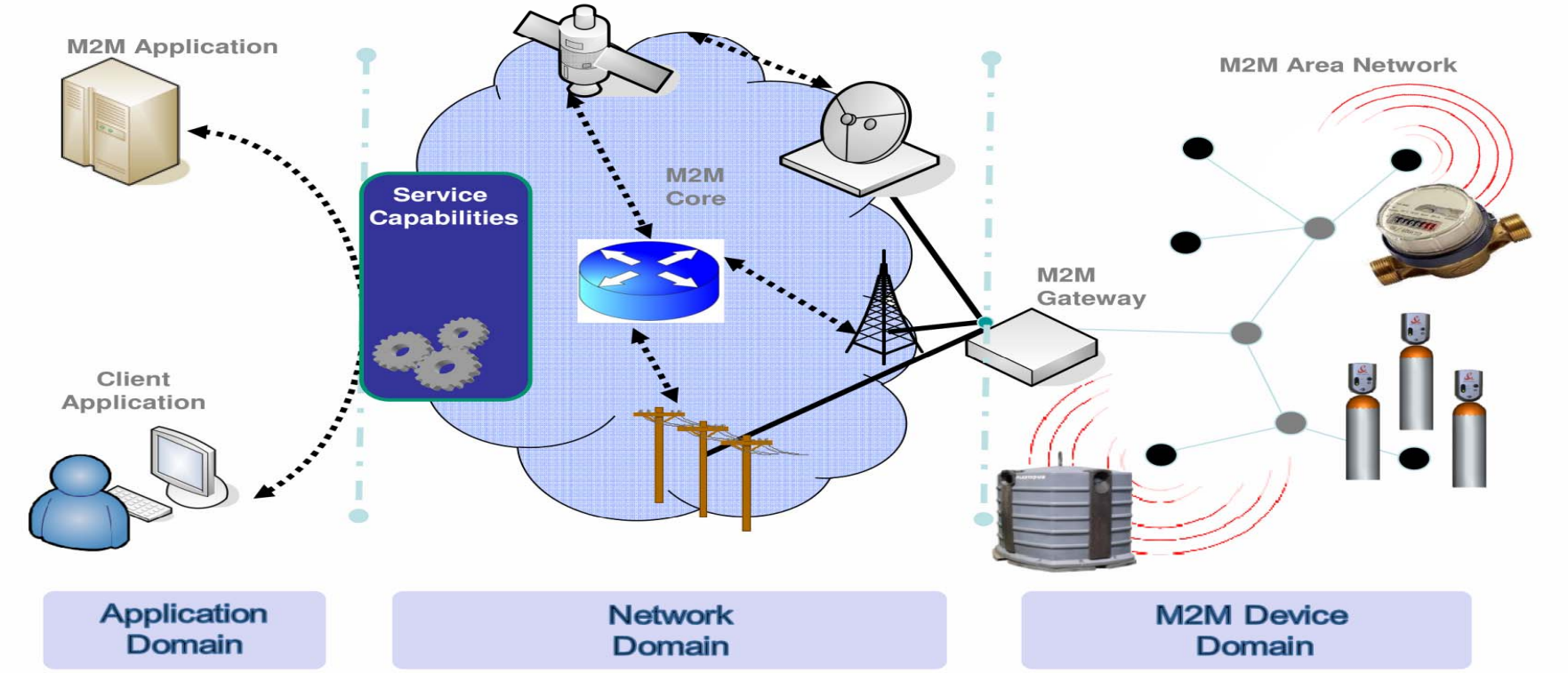
- The M2M component

The network domain

- The M2M area network
- The M2M gateway

The application domain.

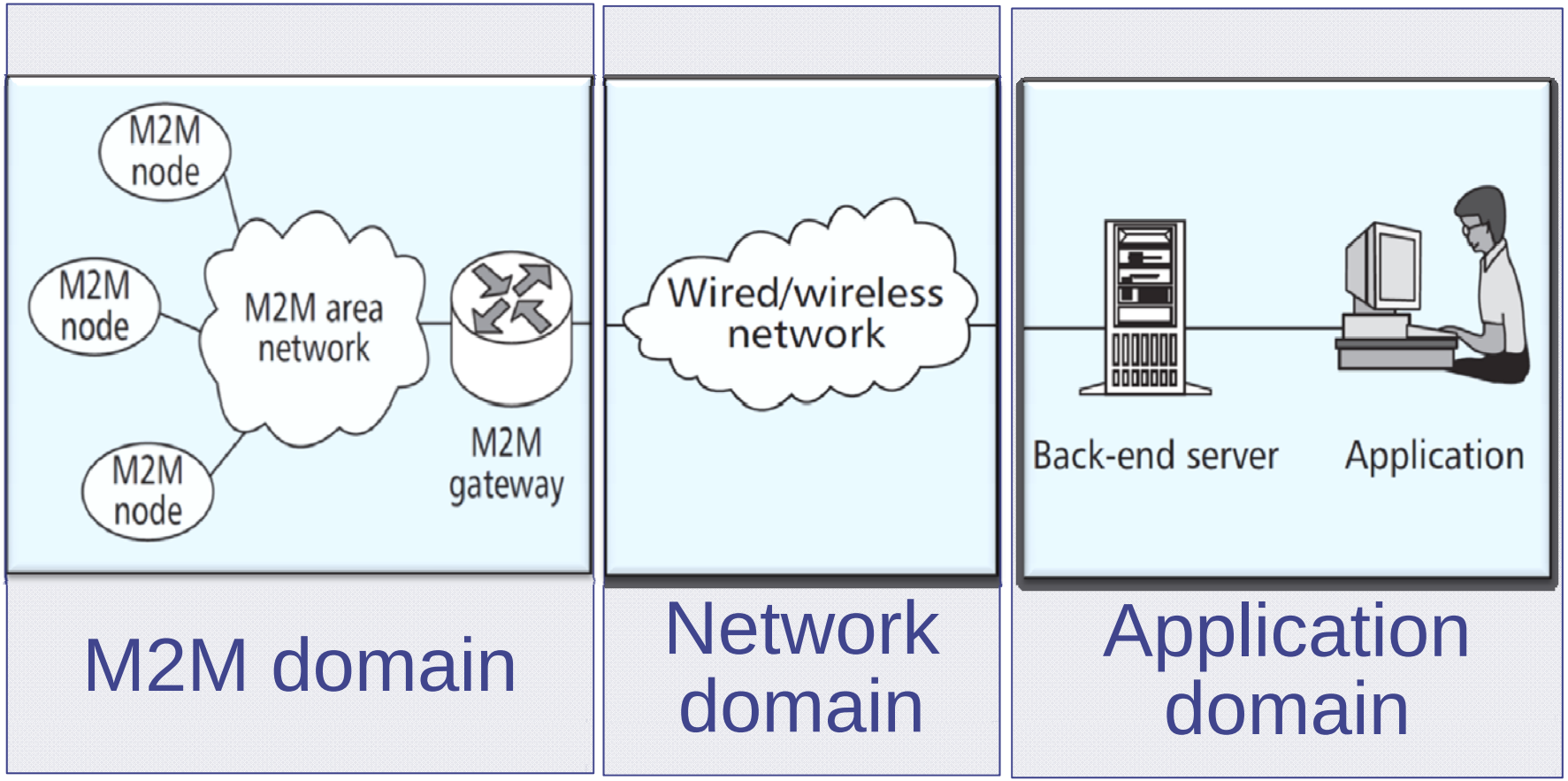
- The M2M server
- The M2M communication network.



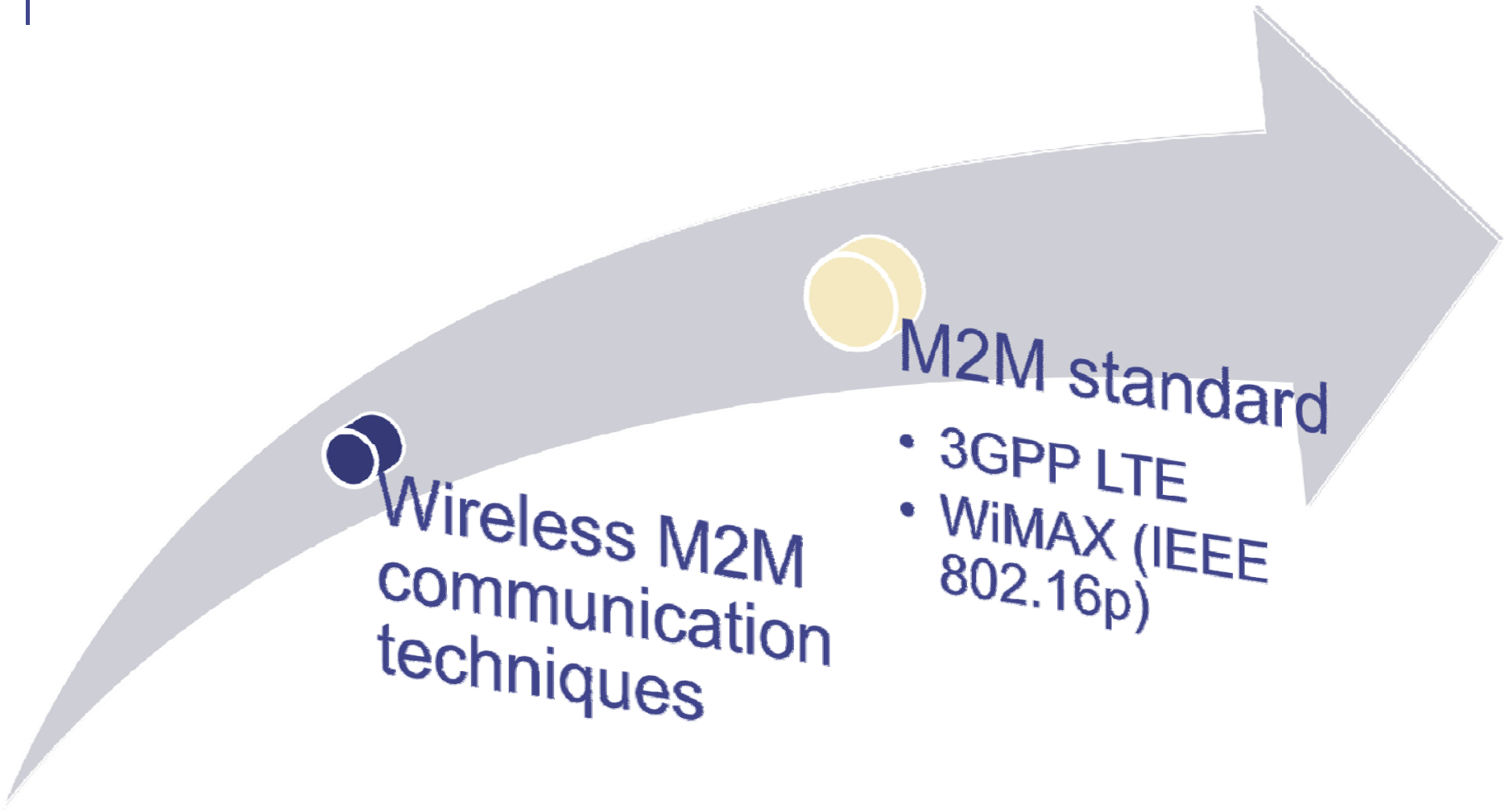
M2M Network Architecture-ETSI

The M2M component,	• usually embedded in a smart electrical device, replies to requests or transmits data.
The M2M area network	• provides connectivity between M2M components and M2M gateways.
The M2M gateway	• enables connectivity between the M2M components and the communication network.
The M2M server	• works as a middleware layer to pass data through various application services.
The M2M communication network	• provides connection between M2M gateways and M2M servers.

M2M Network Architecture-IEEE



Wireless M2M Communications



Wireless M2M Communications

- The advances in wireless technologies that enable mobility and eliminate the need for cable installation for M2M components have pushed the development of wireless M2M communications.
- Since different M2M components vary in types and sizes, and may be located in remote areas with limited accessibility, wireless access is more cost effective and flexible for deployment.

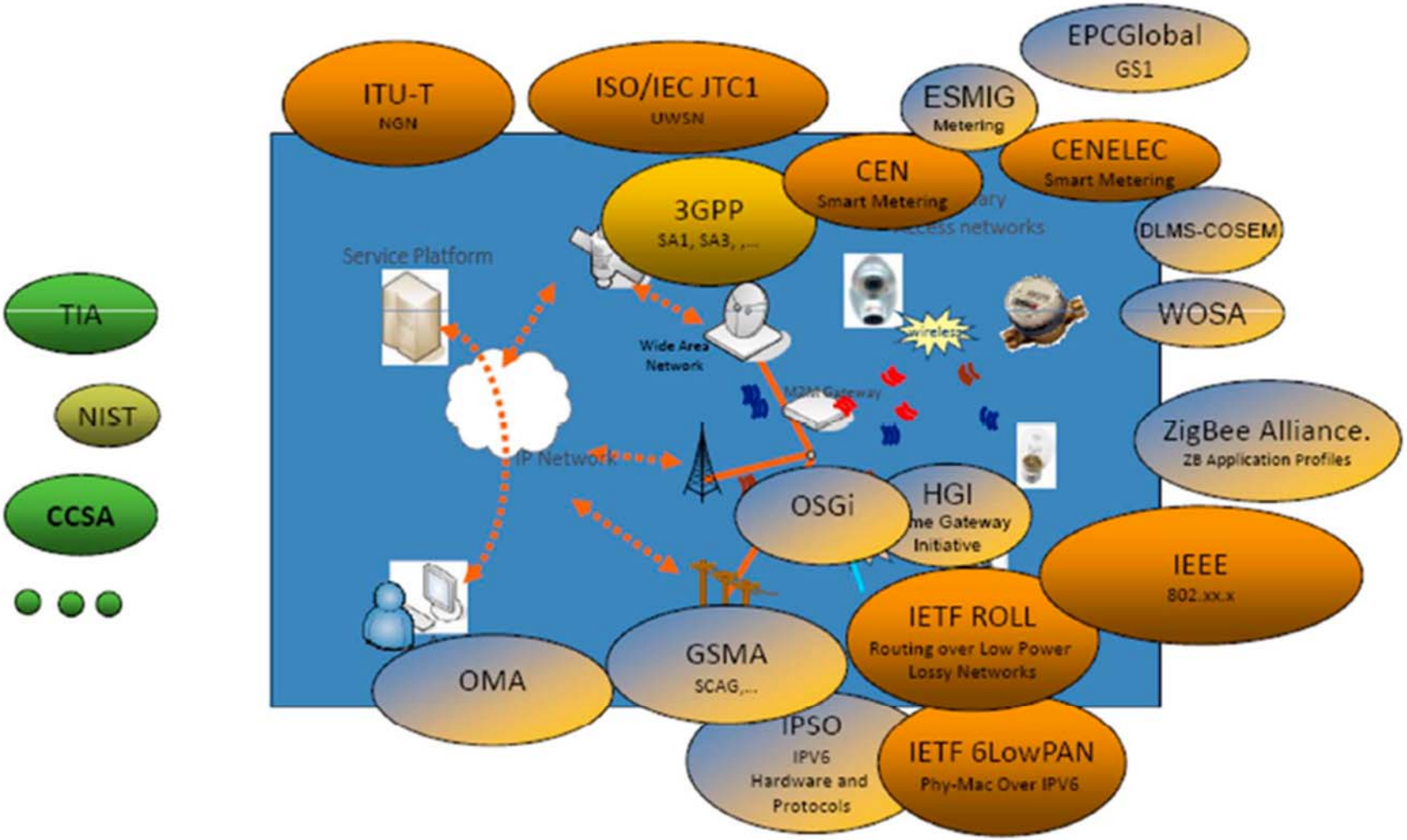
Wireless M2M Communications

- Enabling Wireless Technologies for M2M Communications — Advanced wireless communication technologies are the key enablers for M2M communications. To realize a unified architecture of M2M communications, M2M networks are required to bridge seamlessly with various communication systems by supporting multiple communication technologies:
  - mobile broadband communications
    - (e.g., **W**orldwide **I**nteroperability for **M**icrowave **A**ccess [WiMAX] and **L**ong **T**erm **E**volution [LTE])
  - local area networking
    - (e.g., WiFi)

Wireless M2M Communication Techniques

Standard	Area	Rate	Energy-constrained	Typical applications	Data Type
Zigbee	Personal area	Low	Yes	Automatic control	Sensors, monitoring, smart grid
Bluetooth	Personal area	Low	Yes	Music sharing	Voice, low-rate data, music
UWB	Personal area	High	No	Video, file sharing	Video, high-rate data, files
802.15.6	Body area	Low	Yes	Healthcare	Biomedical data
WiFi	Local area	High	No	Home thermostats, water metering	VoIP, data, video
Femtocell	Local area	High	No	Cellular phones	VoIP, data, video

M2M Standard



Wireless M2M Communication Standard

3GPP LTE

Machine Type Communication

WiMAX

IEEE 802.16p

Wireless M2M Communication Standard - 3GPP LTE

3GPP LTE

- M2M in LTE
- LTE M2M Features
- LTE M2M Architecture
- LTE M2M Applications

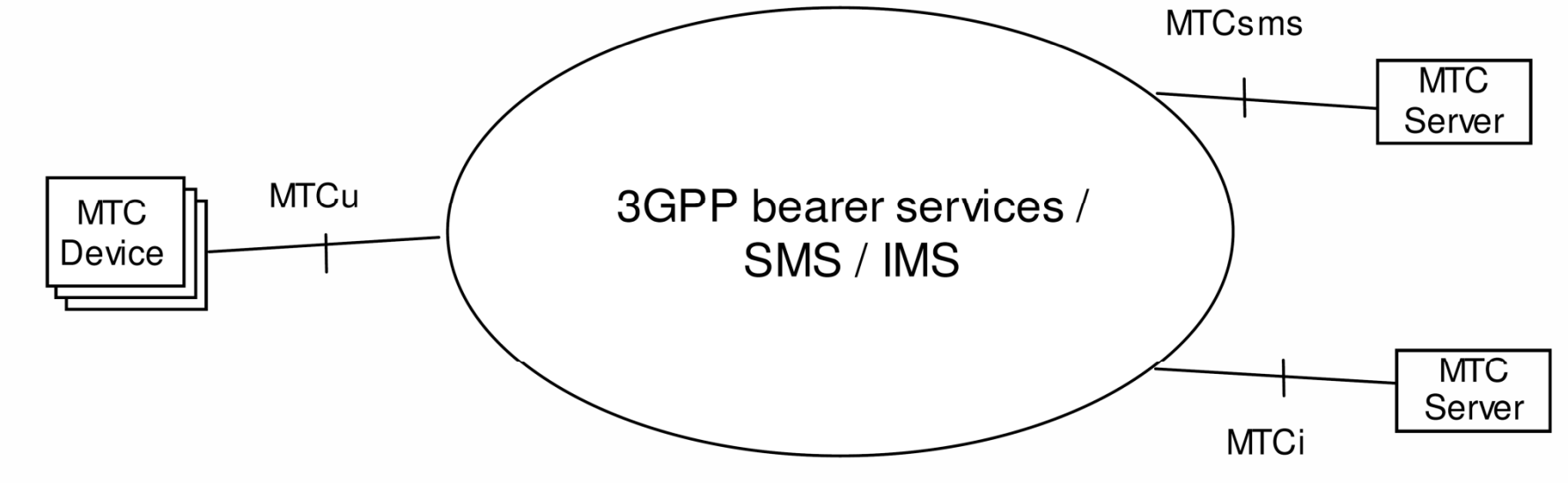
M2M in LTE

- Machine type communication (MTC) is a form of data communication which involves one or more entities that do not necessarily need human interaction.
- A service optimized for machine type communications differs from a service optimized for Human to Human communications.
  - different market scenarios
  - data communications
  - lower costs and effort
  - a potentially very large number of terminals
  - in most cases, little traffic per terminal

LTE M2M Features

- Low Mobility
- Time Controlled
- Time Tolerant
- Packet Switched (PS) only
- Small Data Transmission
- Mobile Originated Only
- Infrequent Mobile Terminated
- MTC Monitoring
- Priority Alarm
- Security Connection
- Location Specific Trigger
- Network Provided Destination for Uplink Data
- Infrequent Transmission
- Group Based MTC Features
  - Policing
  - Addressing

M2M Architecture in 3GPP LTE



MTC :	Machine Type Communication
MTCu :	provides MTC devices access to the 3GPP network for the transport of user traffic
MTCi :	the reference point for MTC server to connect the 3GPP network via 3GPP bearer service
MTCsms :	the reference point for MTC server to connect the 3GPP network via 3GPP SMS

LTE M2M Applications

Service Area	MTC applications	
Security	✓Surveillance systems ✓Backup for landline ✓Car/driver security	✓Control of physical access (e.g. to buildings)
Tracking & Tracing	✓Fleet Management ✓Order Management ✓Pay as you drive ✓Asset Tracking	✓Navigation ✓Traffic information ✓Road tolling ✓Road traffic optimisation/steering
Payment	✓Point of sales ✓Vending machines	✓Gaming machines
Health	✓Monitoring vital signs ✓Remote diagnostics	✓Web Access Telemedicine points ✓Supporting the aged or handicapped
Remote Maintenance/Control	✓Sensors ✓Lighting ✓Pumps ✓Valves	✓Elevator control ✓Vending machine control ✓Vehicle diagnostics
Metering	✓Power ✓Gas ✓Water	✓Heating ✓Grid control ✓Industrial metering
Consumer Devices	✓Digital photo frame ✓Digital camera	✓eBook

Wireless M2M Communication Standard – WiMAX

WiMAX

- M2M in WiMAX
- WiMAX M2M Features
- WiMAX M2M Architecture
- WiMAX M2M Applications

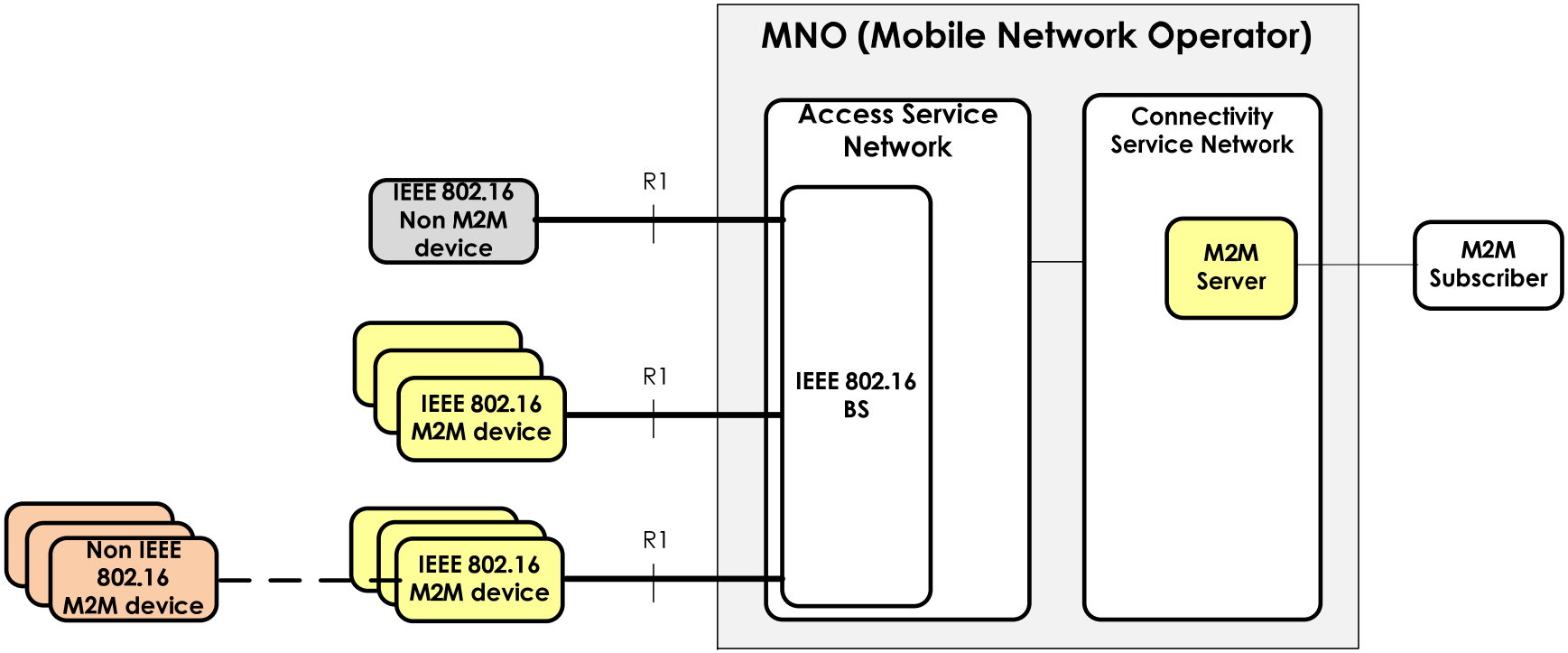
M2M in WiMAX

- Machine to Machine (M2M) service is a data communication between devices through a WiMAX access network, or between a device and a server in the core network through a WiMAX access network that may be carried out without any human interaction.
- Common characteristic of M2M applications:
  - Large number of devices
  - Bursts of data transmission
  - Stationary or low mobility application
  - Automatic resource connection and release from the devices
- Two modes of M2M communication can be identified
  - An M2M Device communicates with one or more servers
  - An M2M Device communicates with another M2M Device

WiMAX M2M Features

- Extremely Low Power Consumption
- High Reliability
- Enhanced Access Priority
- Handling Transmission Attempts from Extremely Large Number of Devices
- Addressing Extremely Large Number of Devices
- Group Control
- Security
- Small Burst Transmission
- Low/No Mobility
- Time-Controlled Operation
- Time-Tolerant Operation
- One-way Data Traffic
- Extremely Low Latency
- Extremely Long Range Access
- Infrequent Traffic

WiMAX M2M Architecture



Terms	Description
M2M device	Embedded device with wireless WAN connectivity
Machine-to-Machine (M2M)	This is information exchange between devices (subscriber station) through a base station, or between a device and a server in the core network through a Base Station that may be carried out without any human interaction.

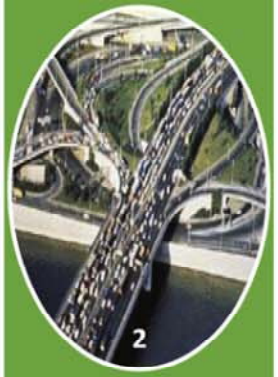
WiMAX M2M Applications

Industry	Example application	Description
Transportation/Automotive	Vehicle/Asset Tracking	This category includes public and private transportation business. The example of public transportation business is bus and train operators. The example of private transportation is equivalent to logistics.(e.g. DHL, etc)
Security & Safety	Home Alarm, Surveillance	This category includes CCTV cameras and other remote sensors that may monitor the presence of person or functions of equipment.
Smartgrid and Smart Metering	Electricity, Gas, Water, industrial metering	This category includes metering applications provided by utilities operators.
Healthcare	Monitoring vital signs, Remote diagnostics, supporting of seniors or handicapped	This category includes hospitals and other entities applications that provide healthcare services either their premise or remotely.
Remote Management/Control	Industrial Automation, Vending machine, Elevator control, Traffic Lighting, Flood management, Telemetry	This category includes manufacturing, in-vehicle, in-building and roadside machines.
Telematics	Roadside assistance & remote diagnosis	This category includes automobile systems that combine GPS technology and other wireless communication systems for automatic roadside assistance and remote diagnostics
Mobile Payment	Credit card or debit card payment	This category includes the street meter post payment, the vending machine payment and credit card swipe for any wireless payment.

M2M Application

Building Management

- HVAC Control / Automation
- Lighting Control / Automation
- Structural Health Monitoring
- Energy / Utility Monitoring
- Building Awareness / Security
  - Entry Control
  - Fire Detection, Intruder detection
  - Elevators, doors, etc.



Transportation and Logistics (ITS)

- Mass Transit
- Stop Light Management
- Parking Control
- Toll Payment
- Inventory Monitoring
- Vehicle and Asset tracking
- Driver safety
- Accident notification
- Location positioning

Medical

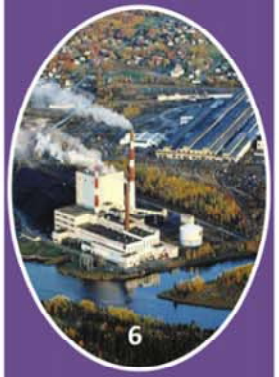
- Portable Devices
- Remote Healthcare
- Individual Monitoring for the Elderly
- Consumer Medical

Local Communities and Public Safety

- Site surveillance
- Air Quality Monitoring
- Billboards
- Point of Sale
- Vending Machines
- Public lighting
- First-responder Sysems
- Border / Perimeter Security

Energy / Utilities

- Smart Grid Monitoring (Smart metering)
- Substation Integration
- Distribution Automation
- Utility Sub-metering
- Oil / Gas Production Monitoring
- Water treatment and supply
- Billing of utilities (Oil, water, electricity, heat, etc.)



Manufacturing / Industrial

- Plant Operations / Safety
- Instrument Calibration
- Machine Health Monitoring
- Process Control and Automation
- Condition-based Maintenance

M2M Application

- Smart Grid Monitoring
- Substation Integration
- Distribution Automation
- Utility Sub-metering
- Oil/ Gas Production Monitoring
- Water treatment and supply
- Billing of utilities

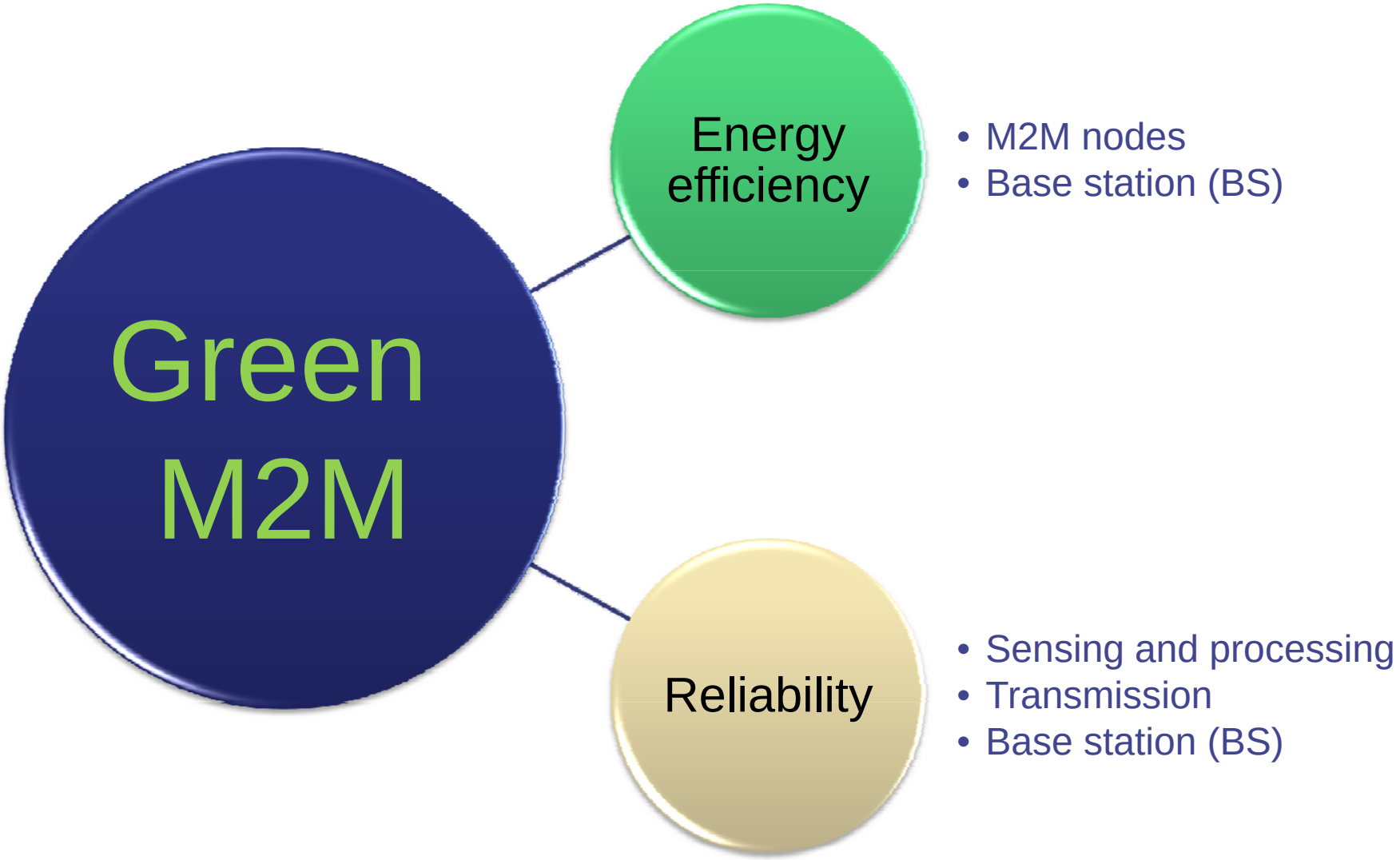
Energy / Utilities

- Smart Grid Monitoring (Smart metering)
- Substation Integration
- Distribution Automation
- Utility Sub-metering
- Oil / Gas Production Monitoring
- Water treatment and supply
- Billing of utilities (Oil, water, electricity, heat, etc.)

2. Green M2M

1. Background
2. Green M2M
3. Green M2M application
4. Open research issues

2. Green M2M


Green M2M
Energy efficiency
• M2M nodes
• Base station (BS)
Reliability
• Sensing and processing
• Transmission
• Base station (BS)

Characteristics of Green M2M

- Green
  - Since a mass of M2M nodes are deployed in the M2M domain, M2M communications should focus on energy saving by optimizing **M2M nodes' sensing, processing, and transmissions**, and ultimately prolong the lifetime of the whole M2M communications. In addition, since the BS is also a **power-consuming** component in M2M communications, great efforts should also be made on the BS to achieve environmentally friendly, green M2M communications.
- Reliability
  - Reliability is critical for green M2M communications, because unreliable sensing, processing, and transmission can cause false monitoring data reports, long delays, and even data loss, which would reduce people's interest in M2M communications. Therefore, the rapid growth of M2M communications demand of high-reliability.

Energy Efficiency for Green M2M

- Since a mass of M2M nodes are deployed in the device domain, M2M communications should focus on energy saving by optimizing M2M nodes' sensing, processing, and transmissions, and ultimately prolong the lifetime of the whole M2M communications. In addition, since the BS is also a power-consuming component in M2M communications, great efforts should also be made on the BS to achieve environmentally friendly, green M2M communications.

3. Green M2M application

1. Background
2. Green M2M
3. Green M2M application
   - Green M2M application in home
   - Green M2M application in building
   - Green M2M application in wireless sensor network (WSN)
   - Green M2M application in vehicular
   - Green M2M application in monitor
4. Open research issues

Green M2M Application in Home

- Green M2M application in home
  - Smart grid
  - A general model of the smart grid
  - M2M communications for HEMS in smart grid
  - Indoor home M2M networks architecture
- Green M2M application in building
- Green M2M application in wireless sensor network (WSN)
- Green M2M application in vehicular
- Green M2M application in monitor

Smart Grid

- The smart grid is one of the strongest driving forces for M2M communications. It is a new paradigm of designing and operating the electrical power system with the objective to improve efficiency, enhance service quality, and save cost in power generation, distribution, and consumption.
- Smart grid applications based on the current power grid system could be problematic since the century-old power line systems were not designed to meet modern requirements, while reconstruction of power line systems for smart grid applications would be costly and time-consuming.

Smart Grid

- To address this issue, [1] incorporates cellular technologies with power line systems. Specifically, cell phones are used as an instrument to display information and allow consumers to control appliances in their homes in addition to the deployment of smart meters. Through this, smart grid applications can be realized economically and conveniently.

[1]Smart Demand-Side Energy Management based on Cellular Technology — A Way Towards Smart Grid Technologies in Africa and Low Budget Economies,

A General Model of The Smart Grid

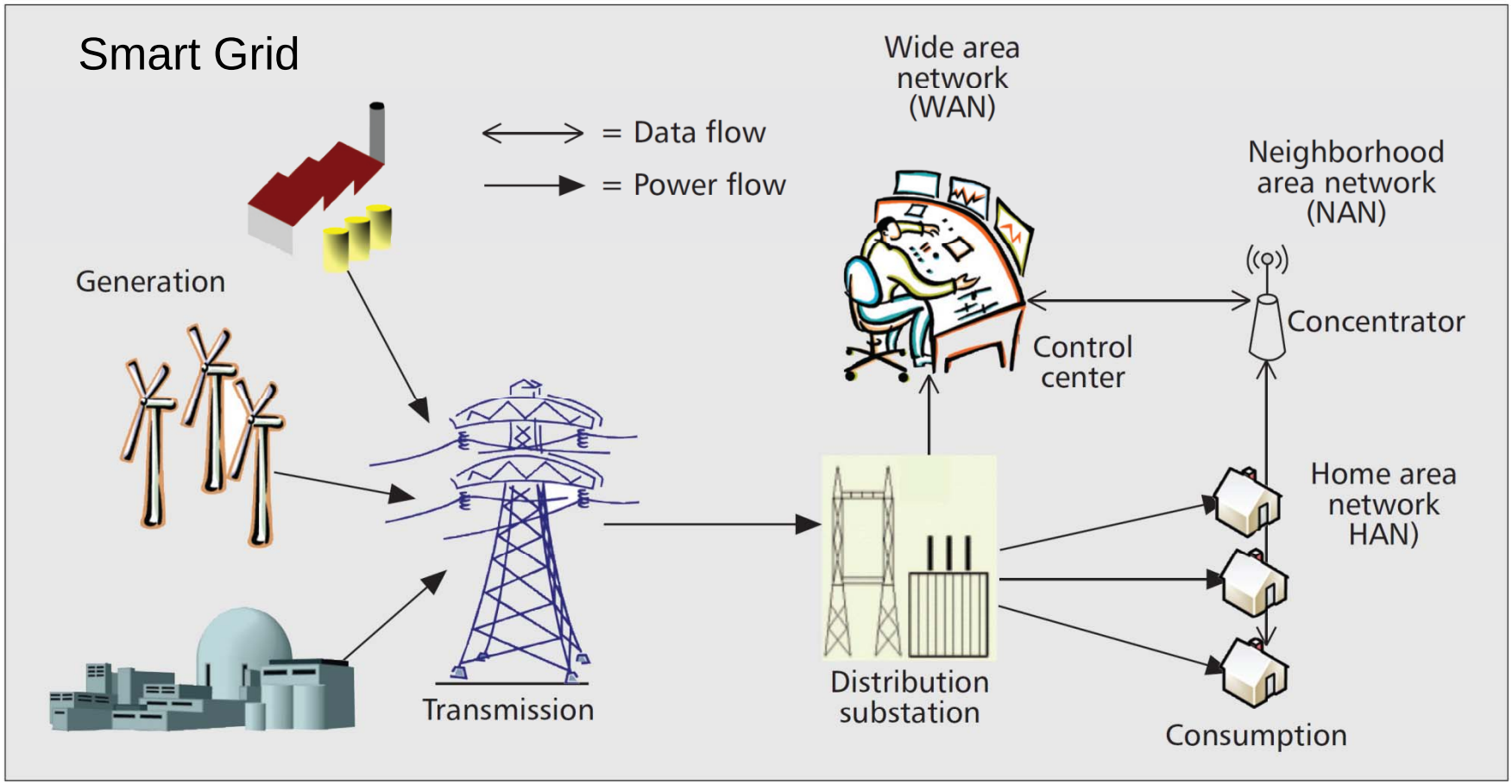


Figure 1. *A general model of the smart grid.*

M2M Communications for HEMS in Smart Grid

- HEMS
  - Home Energy Management System
- focuses on the power consumer side in a smart grid in which home appliances (e.g., air conditioner, dishwasher, dryer, refrigerator, kitchen stove, and washing machine) with smart meters can be monitored and controlled by a control center to optimize the power supply and consumption.
- consumers can track the power consumption and perform optimization to reduce power costs. M2M communications play a crucial role in a HEMS since information about home appliances has to be transferred to the control center for analysis and optimization.

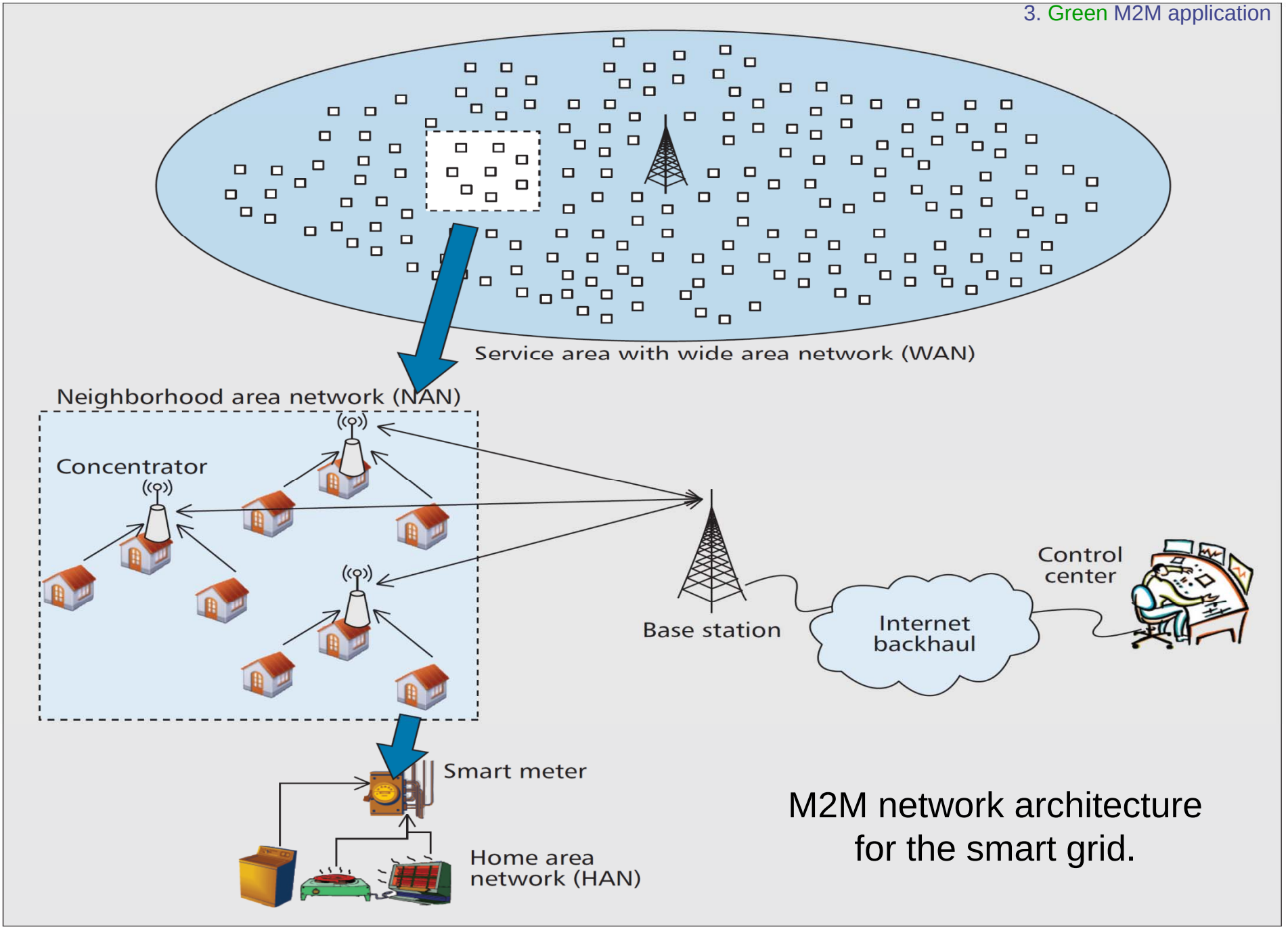


Figure 2. *M2M network architecture for the smart grid.*

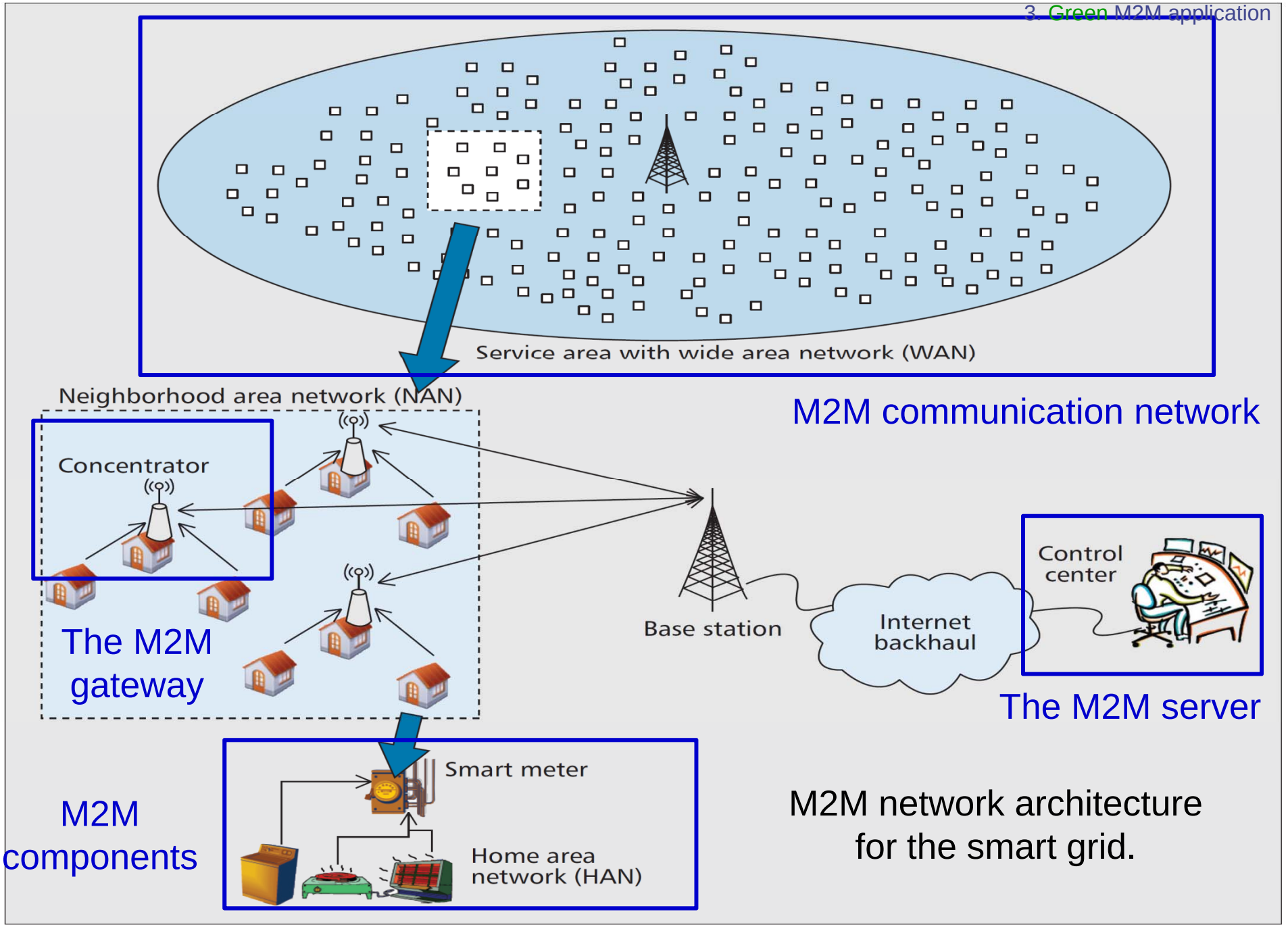
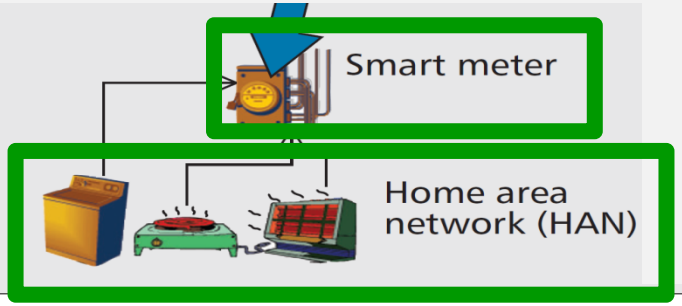


Figure 2. *M2M network architecture for the smart grid.*

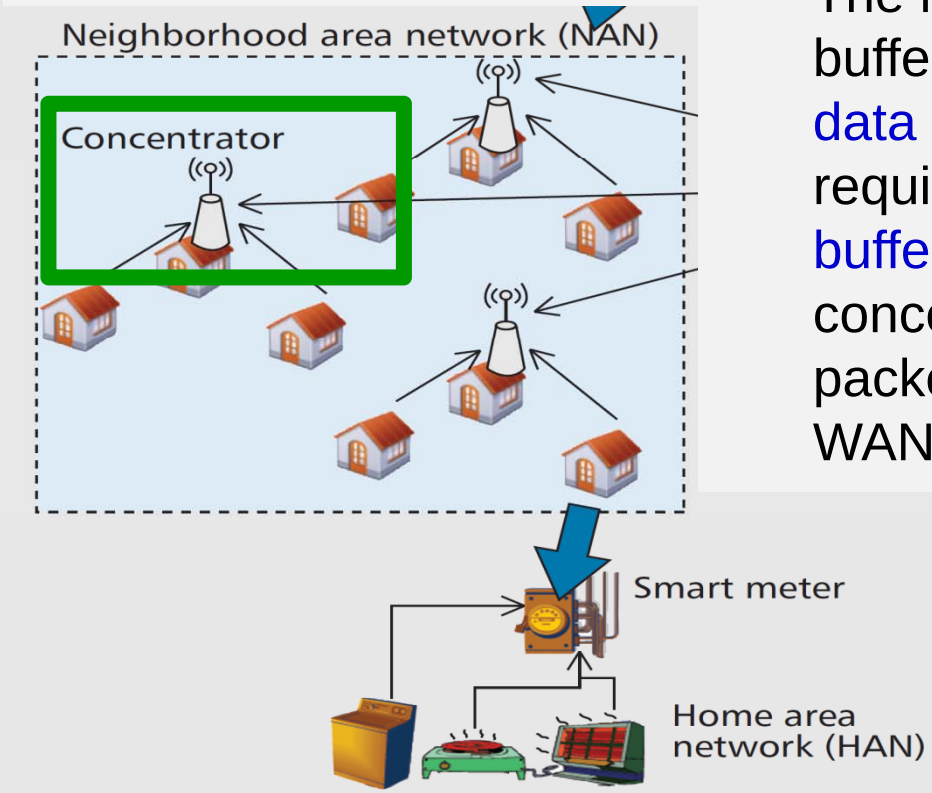
- Smart meter
  - A smart meter is a device used to collect the power consumption demand data from home appliances. A home area network (HAN) can be established among home appliances and a smart meter (e.g., using power line communication [PLC] or ZigBee).



- Home appliance
  - A home appliance is a power consumption device in the smart grid. Home appliances in a house are connected to a smart meter, and their power consumption is measured and collected by the smart meter. Alternatively, advanced home appliances can proactively send reports to the smart meter (e.g., future power consumption demand).

Figure 2. *M2M network architecture for the smart grid.*

- Concentrator
  - A neighborhood area network (NAN) is established among smart meters of the houses in an area to support the HEMS. A NAN has a concentrator (i.e., gateway) to collect data packets (i.e., HEMS traffic) from smart meters using short-range communication technologies (e.g., WiFi). The received packets are stored in the buffer of the concentrator. Different types of data packets with different QoS requirements can be stored in different buffers. The WAN transceiver of the concentrator retrieves a head-of-queue packet from the buffer and transmits it to a WAN base station.



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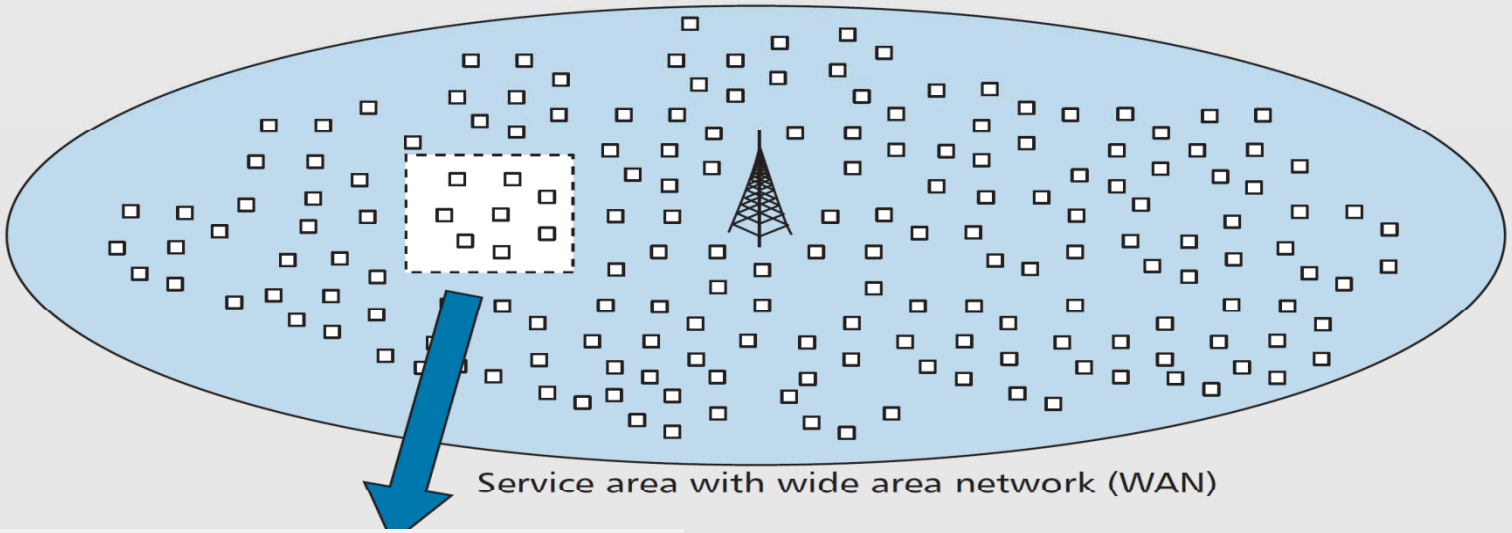
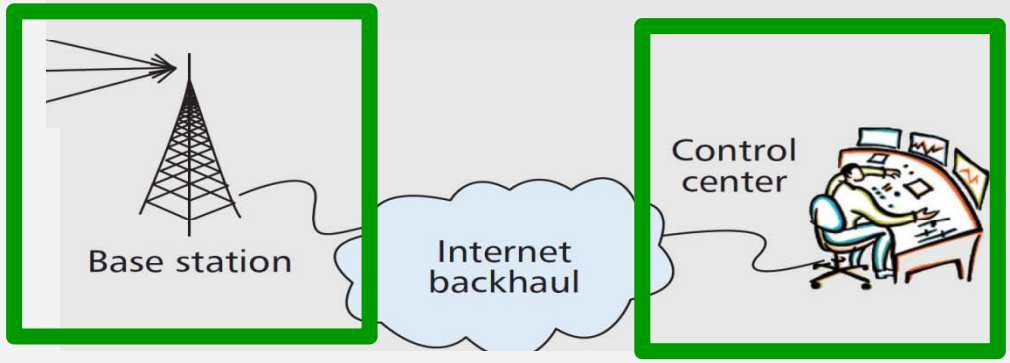


- WAN base station:
  - A WAN base station is in charge of bandwidth allocation for the data transmission of each concentrator. After the data packets sent from concentrators are received by the WAN base station, they are then forwarded over the wired network (e.g., Internet backhaul to the control center.



- Control center:
  - The control center receives HEMS data for processing and storage. This data is used to optimize the electrical power generation and/or distribution.

Figure 2. *M2M network architecture for the smart grid.*

M2M Communications for HEMS in Smart Grid

- In the context of M2M communications as described earlier, M2M components are the home appliances and smart meters. The M2M gateway is the HEMS traffic concentrator. The M2M server is located at the control center. M2M area network is based on short-range communication technologies (e.g., Wi-Fi), and an M2M communication network is a WAN (e.g., IEEE 802.16).

Indoor Home M2M Networks Architecture

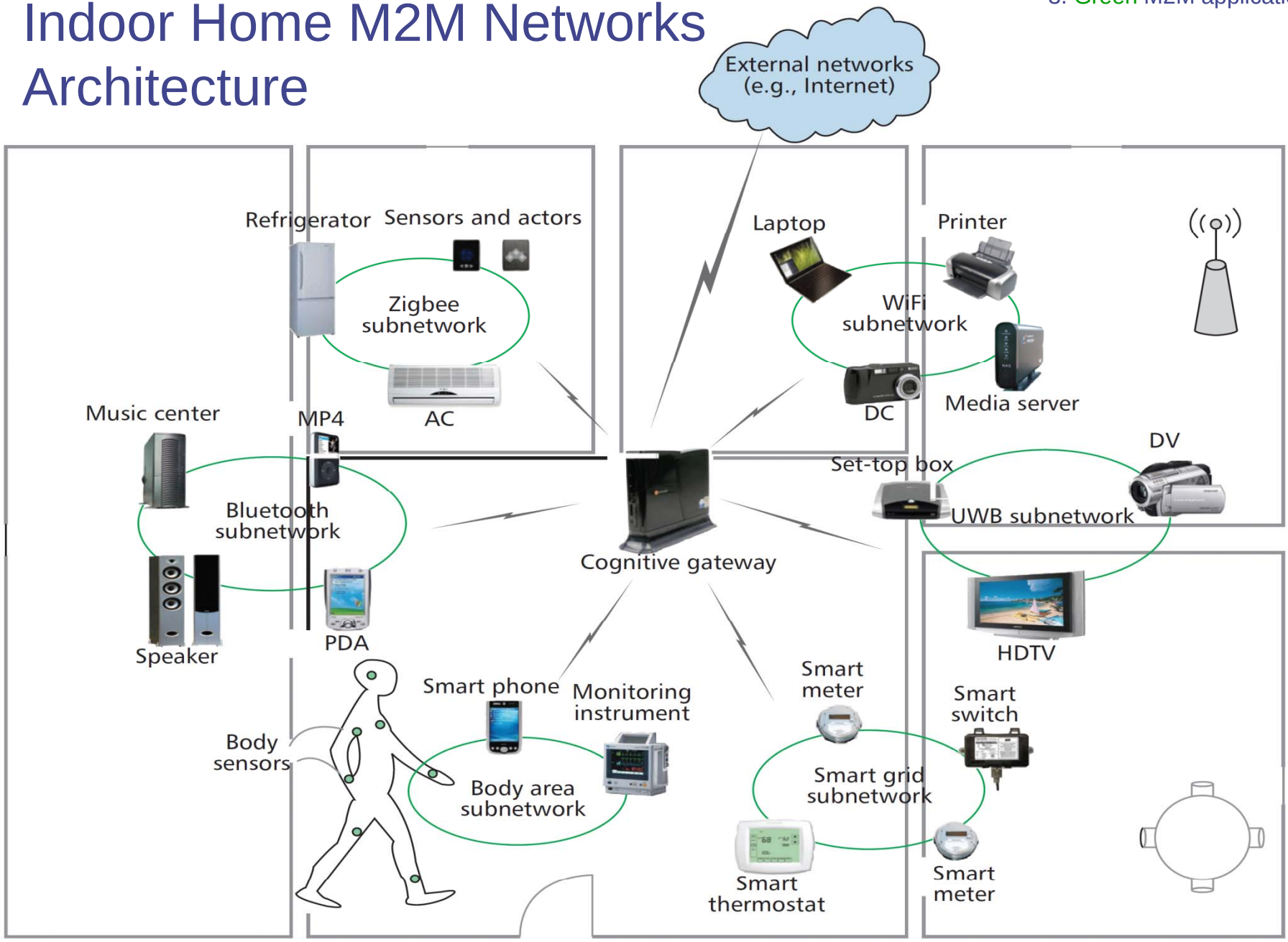


Figure 1. *Proposed home M2M networks architecture.*

M2M Gateway Architecture

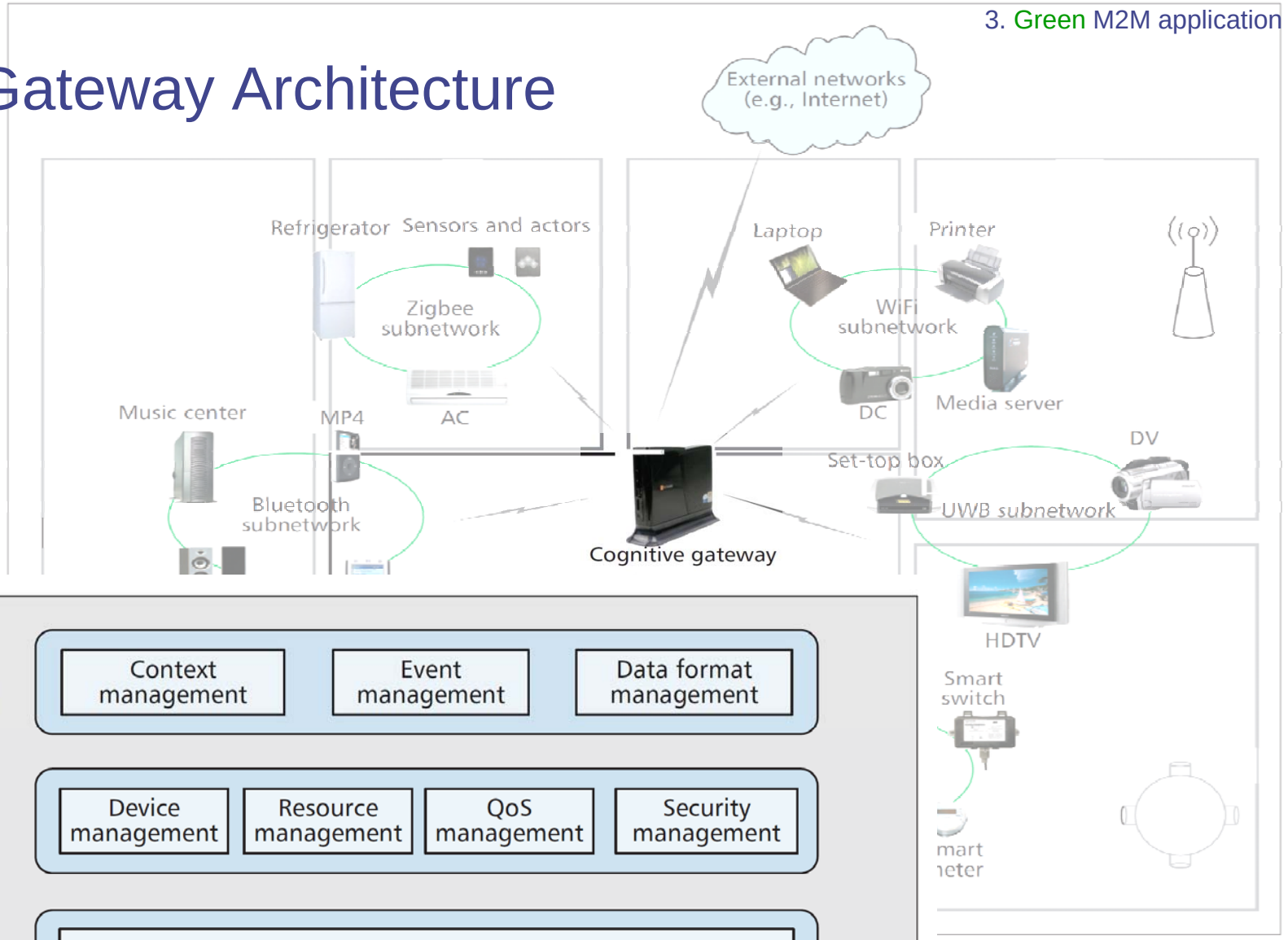


Figure 2. *HGW architecture.*

Green M2M Application in Building

- Green M2M application in home
- Green M2M application in building
  - Smart building
- Green M2M application in wireless sensor network (WSN)
- Green M2M application in vehicular
- Green M2M application in monitor

Smart Building

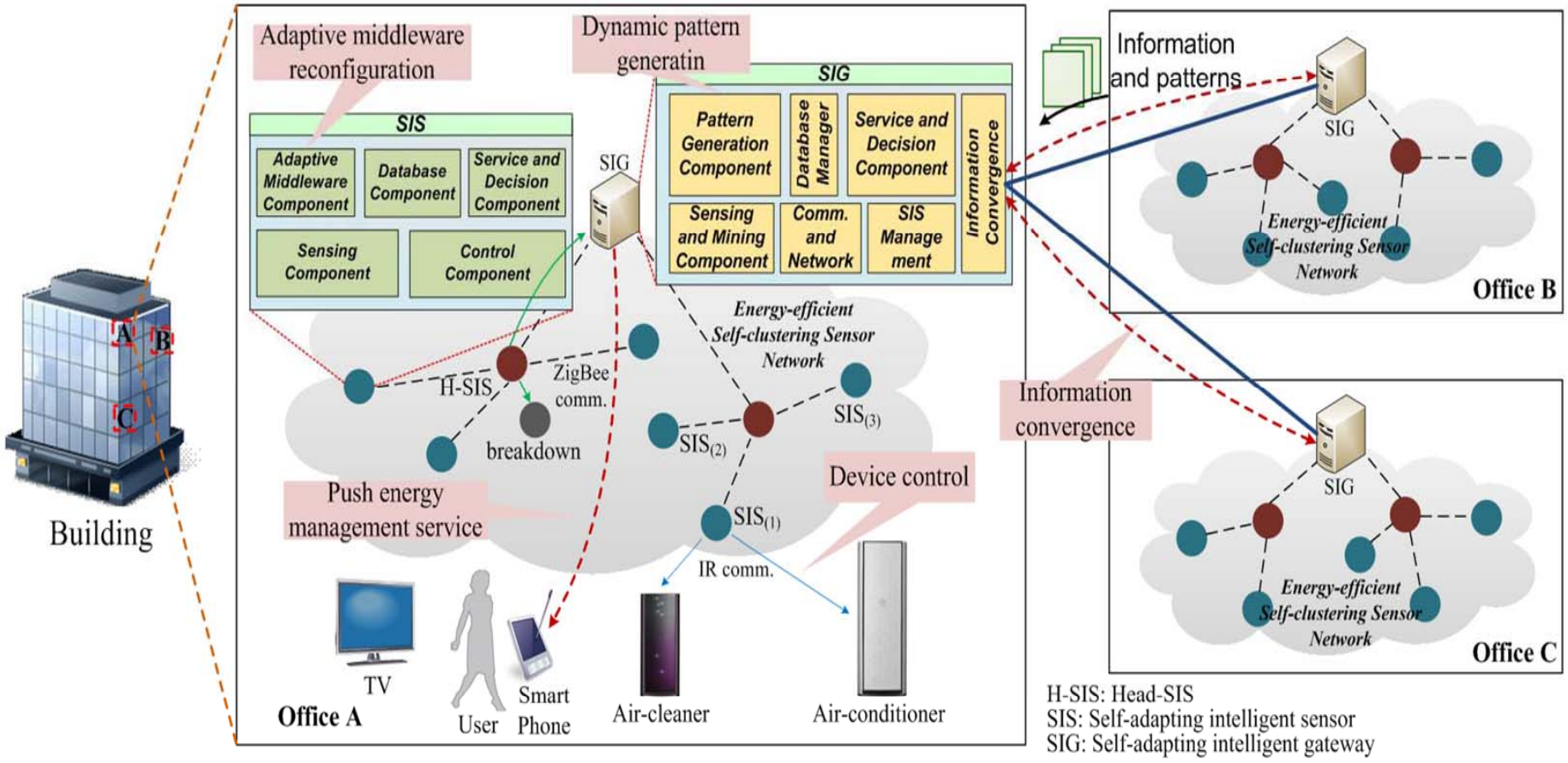


Fig. 1. Overview of the self-adapting intelligent system architecture

Green M2M Application in WSN

- Green M2M application in home
- Green M2M application in building
- Green M2M application in wireless sensor network (WSN)
  - Energy-saving room
- Green M2M application in vehicular
- Green M2M application in monitor

The Decision On Full Coverage

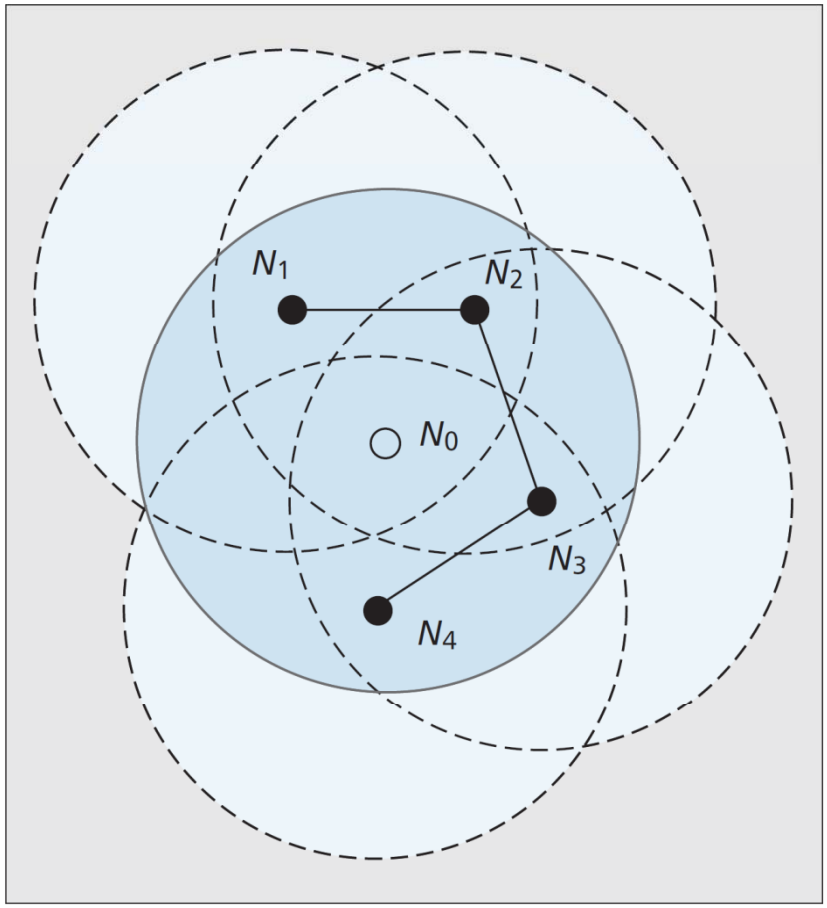


Figure 3. *An example that node* N_0 *may switch to sleep mode because its sensing range is fully covered by the connected neighbors* N_1, …, N_4.

if there are at least two coverage circles, and any intersection point of the two circles inside the sensing area is covered by a third coverage circle, the sensing area is fully covered. Some nodes may have announced themselves as active, and later, after receiving new announcements from neighbors, find that they are fully covered. In this case, they may change their previous decisions and enter sleep mode after announcing their new decisions.

Energy-Saving Room

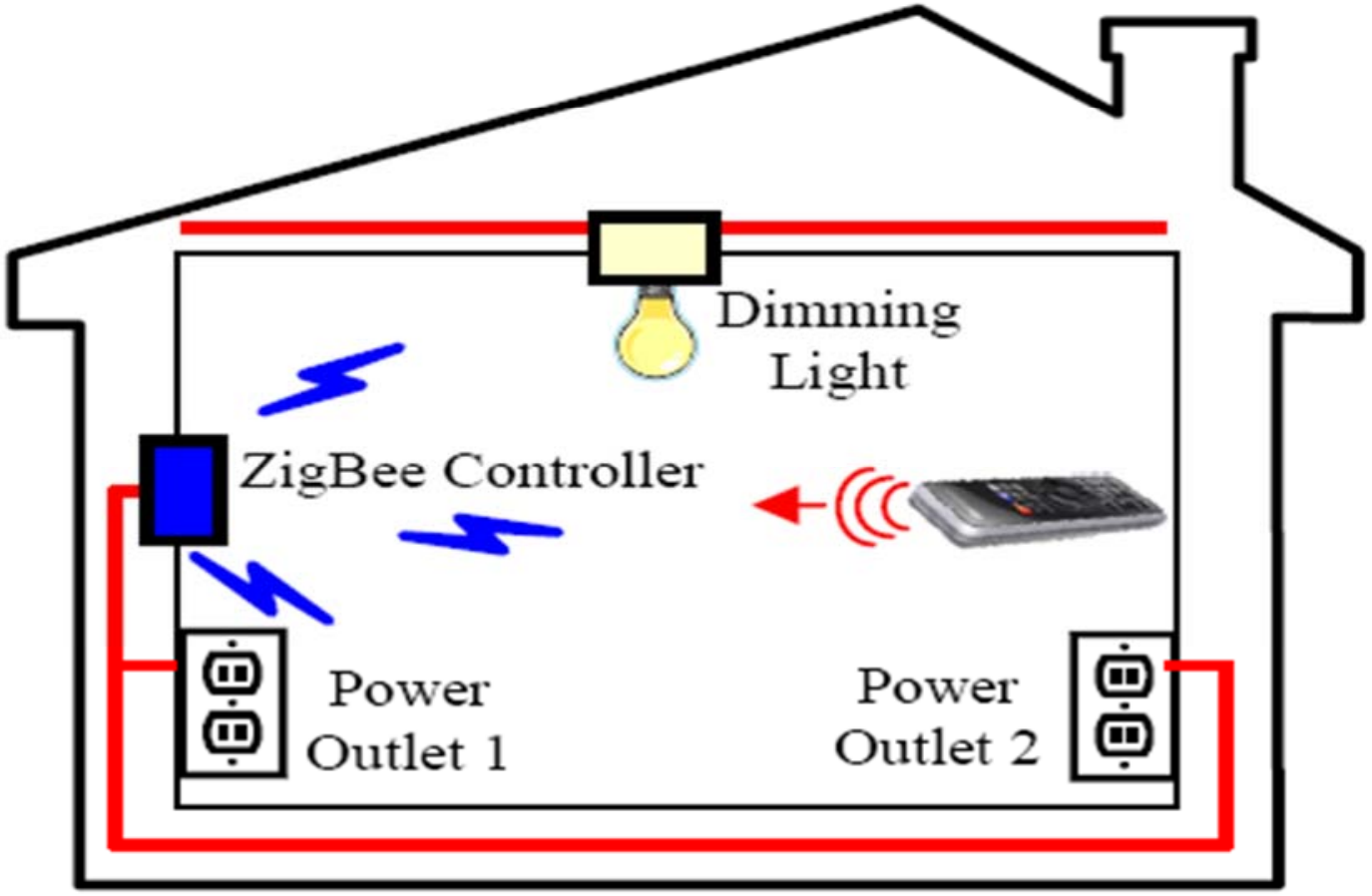
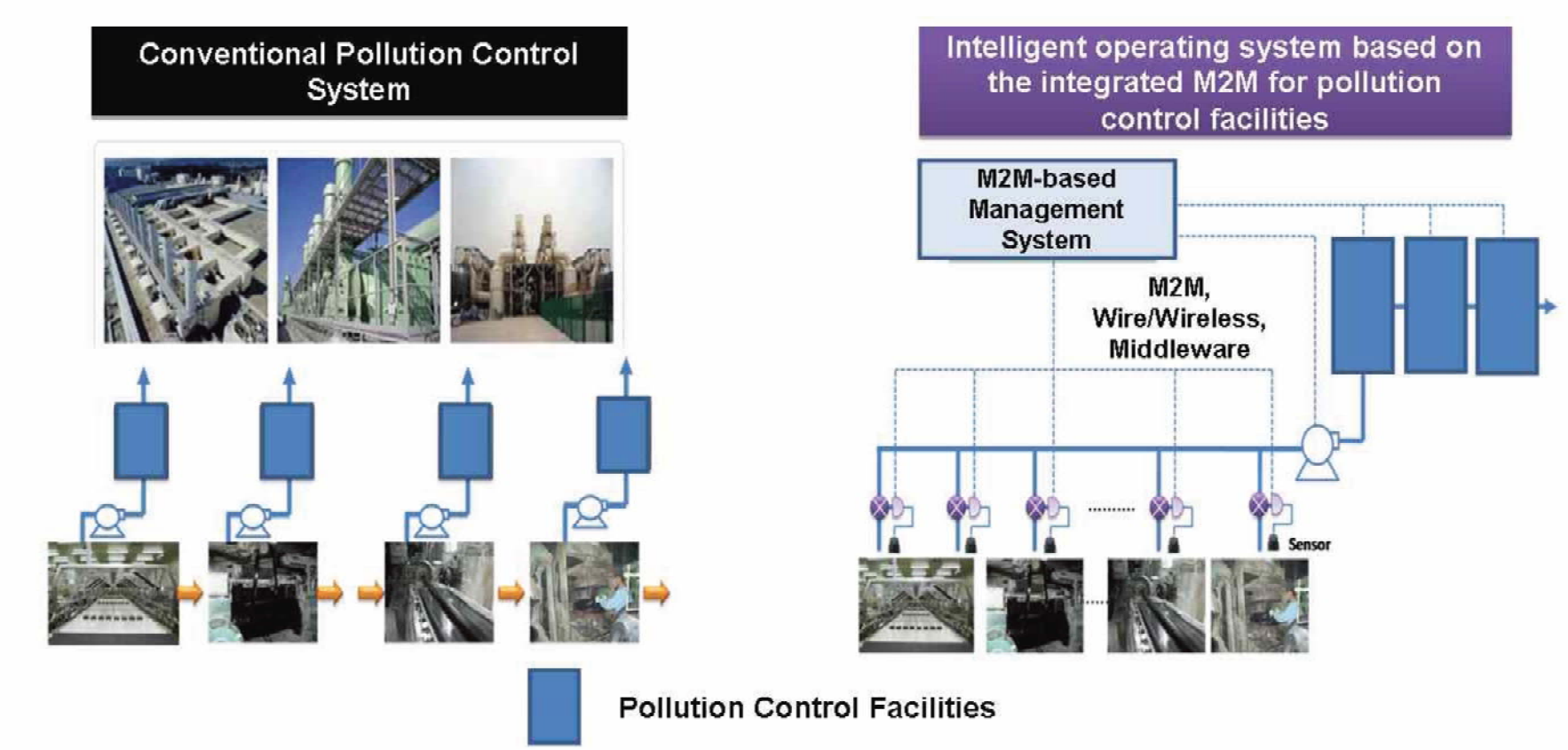


Fig.2. Proposed Room Architecture

Green M2M Application in Vehicular

- Green M2M application in home
- Green M2M application in building
- Green M2M application in wireless sensor network (WSN)
- Green M2M application in vehicular
- Green M2M application in monitor

A Design of M2M-based Intelligent Operating System for Effective Pollution Control Facilities



4. Open research issues

1. Background
2. Green M2M
3. Green M2M application
4. Open research issues

4. Open Research Issues

- Standardization
  - M2M communications will require an integration and convergence among various different communications systems (e.g., local and wide area networks).
- Traffic Characterization
  - Characteristics of traffic exchanged among M2M components have not been well studied so far. Traffic characterization is the fundamental to the design and optimization of network infrastructures. M2M traffic characterization is also required to provide quality of service (QoS) support for M2M applications.
- Protocol Re-design
  - The current leading transmission protocols of the Internet, TCP/IP, are known to be inefficient for M2M traffic due to the redundant and energy-wasting overhead compared to the low data volume needing to bring transmitted.

4. Open Research Issues (cont.)

- Spectrum Management
  - Due to the limited spectrum resource, wireless M2M technologies need to efficiently transmit signals over frequency channels. However, traditional static spectrum allocation may not be able to achieve optimal spectrum management, due to the inevitable shift of spectrum requirements in the supply and demand for wireless M2M services.
- Optimal Network Design
  - As M2M communications will connect a number of devices and systems together, the optimal network design is an important issue. The network design has to minimize cost of M2M communications (e.g., hardware, maintenance, and radio resource usage) while meeting QoS requirements of the traffic and applications.

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Homework#5:

1. Please try to explain the M2M architecture of ETSI and IEEE, respectively.

2. What are the characteristics of Green M2M ?

3. Please try to think and provide a new possible Green M2M application.