Chapter 5: Green Wireless Communication via M2M

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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

The Six Pillars of M2M

REMOTE MONITORING  RFID  SENSOR NETWORKING  SMART SERVICES  TELEMATICS  TELEMETRY

People <-> Devices <-> Systems
Machine to Machine Communication

1. Background

- M2M overall framework
- Definition
- Difference
- Constraints
- M2M network architecture
From IoT to M2M
Definition

■ Characteristics
  • low power
  • low cost
  • low human intervention

■ Composition
  • Networked devices
  • Gateway

■ M2M communications

Data collection
  • Refers to the procedure used to obtain the physical data

Data transmission
  • Includes the mechanisms to deliver the collected data from the communications area to an external server

Data processing
  • The process of dealing with and analyzing the data, and also provides feedback on how to control the application.
1. Background

**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].
1. Background

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

---

[Diagram showing the network architecture with components and connections]
## M2M Network Architecture-ETSI

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>The M2M component</td>
<td>usually <em>embedded in a smart electrical device</em>, replies to requests or transmits data.</td>
</tr>
<tr>
<td>The M2M area network</td>
<td>provides connectivity between M2M components and M2M gateways.</td>
</tr>
<tr>
<td>The M2M gateway</td>
<td>enables connectivity between the M2M components and the communication network.</td>
</tr>
<tr>
<td>The M2M server</td>
<td>works as a <em>middleware layer</em> to pass data through various application services.</td>
</tr>
<tr>
<td>The M2M communication network</td>
<td>provides connection between M2M gateways and M2M servers.</td>
</tr>
</tbody>
</table>
1. Background

M2M Network Architecture-IEEE

- M2M domain
- Network domain
- Application domain
Wireless M2M Communications

1. Background

- Wireless M2M communication techniques
- M2M standard
  - 3GPP LTE
  - WiMAX (IEEE 802.16p)
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.
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., **Worldwide Interoperability for Microwave Access** [WiMAX] and **Long Term Evolution** [LTE])

- **local area networking**
  - (e.g., WiFi)
# Wireless M2M Communication Techniques

## 1. Background

<table>
<thead>
<tr>
<th>Standard</th>
<th>Area</th>
<th>Rate</th>
<th>Energy-constrained</th>
<th>Typical applications</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zigbee</td>
<td>Personal area</td>
<td>Low</td>
<td>Yes</td>
<td>Automatic control</td>
<td>Sensors, monitoring, smart grid</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>Personal area</td>
<td>Low</td>
<td>Yes</td>
<td>Music sharing</td>
<td>Voice, low-rate data, music</td>
</tr>
<tr>
<td>UWB</td>
<td>Personal area</td>
<td>High</td>
<td>No</td>
<td>Video, file sharing</td>
<td>Video, high-rate data, files</td>
</tr>
<tr>
<td>802.15.6</td>
<td>Body area</td>
<td>Low</td>
<td>Yes</td>
<td>Healthcare</td>
<td>Biomedical data</td>
</tr>
<tr>
<td>WiFi</td>
<td>Local area</td>
<td>High</td>
<td>No</td>
<td>Home thermostats, water metering</td>
<td>VoIP, data, video</td>
</tr>
<tr>
<td>Femtocell</td>
<td>Local area</td>
<td>High</td>
<td>No</td>
<td>Cellular phones</td>
<td>VoIP, data, video</td>
</tr>
</tbody>
</table>
M2M Standard
Wireless M2M Communication Standard

1. Background

- 3GPP LTE
- IEEE 802.16
- WiMAX

Machine Type Communication

IEEE 802.16p
1. Background

Wireless M2M Communication Standard - 3GPP LTE

3GPP LTE

- M2M in LTE
- LTE M2M Features
- LTE M2M Architecture
- LTE M2M Applications
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
1. Background

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
1. Background

**M2M Architecture in 3GPP LTE**

### MTC
- **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

<table>
<thead>
<tr>
<th>Service Area</th>
<th>MTC applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Security</strong></td>
<td></td>
</tr>
<tr>
<td>✓ Surveillance systems</td>
<td>✓ Control of physical access</td>
</tr>
<tr>
<td>✓ Backup for landline</td>
<td>(e.g. to buildings)</td>
</tr>
<tr>
<td>✓ Car/driver security</td>
<td></td>
</tr>
<tr>
<td><strong>Tracking &amp; Tracing</strong></td>
<td></td>
</tr>
<tr>
<td>✓ Fleet Management</td>
<td>✓ Navigation</td>
</tr>
<tr>
<td>✓ Order Management</td>
<td>✓ Traffic information</td>
</tr>
<tr>
<td>✓ Pay as you drive</td>
<td>✓ Road tolling</td>
</tr>
<tr>
<td>✓ Asset Tracking</td>
<td>✓ Road traffic optimisation/steering</td>
</tr>
<tr>
<td><strong>Payment</strong></td>
<td></td>
</tr>
<tr>
<td>✓ Point of sales</td>
<td>✓ Gaming machines</td>
</tr>
<tr>
<td>✓ Vending machines</td>
<td></td>
</tr>
<tr>
<td><strong>Health</strong></td>
<td></td>
</tr>
<tr>
<td>✓ Monitoring vital signs</td>
<td>✓ Web Access Telemedicine points</td>
</tr>
<tr>
<td>✓ Remote diagnostics</td>
<td>✓ Supporting the aged or handicapped</td>
</tr>
<tr>
<td><strong>Remote Maintenance/Control</strong></td>
<td></td>
</tr>
<tr>
<td>✓ Sensors</td>
<td>✓ Elevator control</td>
</tr>
<tr>
<td>✓ Lighting</td>
<td>✓ Vending machine control</td>
</tr>
<tr>
<td>✓ Pumps</td>
<td>✓ Vehicle diagnostics</td>
</tr>
<tr>
<td>✓ Valves</td>
<td></td>
</tr>
<tr>
<td><strong>Metering</strong></td>
<td></td>
</tr>
<tr>
<td>✓ Power</td>
<td>✓ Heating</td>
</tr>
<tr>
<td>✓ Gas</td>
<td>✓ Grid control</td>
</tr>
<tr>
<td>✓ Water</td>
<td>✓ Industrial metering</td>
</tr>
<tr>
<td><strong>Consumer Devices</strong></td>
<td></td>
</tr>
<tr>
<td>✓ Digital photo frame</td>
<td>✓ eBook</td>
</tr>
<tr>
<td>✓ Digital camera</td>
<td></td>
</tr>
</tbody>
</table>
Wireless M2M Communication Standard – WiMAX

WiMAX

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

1. Background

<table>
<thead>
<tr>
<th>Terms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2M device</td>
<td>Embedded device with wireless WAN connectivity</td>
</tr>
<tr>
<td>Machine-to-Machine (M2M)</td>
<td>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.</td>
</tr>
</tbody>
</table>
## WiMAX M2M Applications

<table>
<thead>
<tr>
<th>Industry</th>
<th>Example application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation/Automotive</td>
<td>Vehicle/Asset Tracking</td>
<td>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).</td>
</tr>
<tr>
<td>Security &amp; Safety</td>
<td>Home Alarm, Surveillance</td>
<td>This category includes CCTV cameras and other remote sensors that may monitor the presence of a person or functions of equipment.</td>
</tr>
<tr>
<td>Smartgrid and Smart Metering</td>
<td>Electricity, Gas, Water, industrial metering</td>
<td>This category includes metering applications provided by utilities operators.</td>
</tr>
<tr>
<td>Healthcare</td>
<td>Monitoring vital signs, Remote diagnostics, supporting of seniors or handicapped</td>
<td>This category includes hospitals and other entities applications that provide healthcare services either their premise or remotely.</td>
</tr>
<tr>
<td>Remote Management/Control</td>
<td>Industrial Automation, Vending machine, Elevator control, Traffic Lighting, Flood management, Telemetry</td>
<td>This category includes manufacturing, in-vehicle, in-building and roadside machines.</td>
</tr>
<tr>
<td>Telematics</td>
<td>Roadside assistance &amp; remote diagnosis</td>
<td>This category includes automobile systems that combine GPS technology and other wireless communication systems for automatic roadside assistance and remote diagnostics</td>
</tr>
<tr>
<td>Mobile Payment</td>
<td>Credit card or debit card payment</td>
<td>This category includes the street meter post payment, the vending machine payment and credit card swipe for any wireless payment.</td>
</tr>
</tbody>
</table>
M2M Application

1. Background
M2M Application

1. Background

- Smart Grid Monitoring
- Substation Integration
- Distribution Automation
- Utility Sub-metering
- Oil/ Gas Production Monitoring
- Water treatment and supply
- Billing of utilities
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
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**.
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.
M2M network architecture for the smart grid.

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

Figure 2. M2M network architecture for the smart grid.
3. Green M2M application

- **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.

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

3. Green M2M application

Fig. 1. Overview of the self-adapting intelligent system architecture
3. Green M2M application

- 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

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.

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

3. Green M2M application

Conventional Pollution Control System

Intelligent operating system based on the integrated M2M for pollution control facilities

M2M-based Management System

M2M, Wire/Wireless, Middleware

Sensor

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.
Reference


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.