CPS: Communications

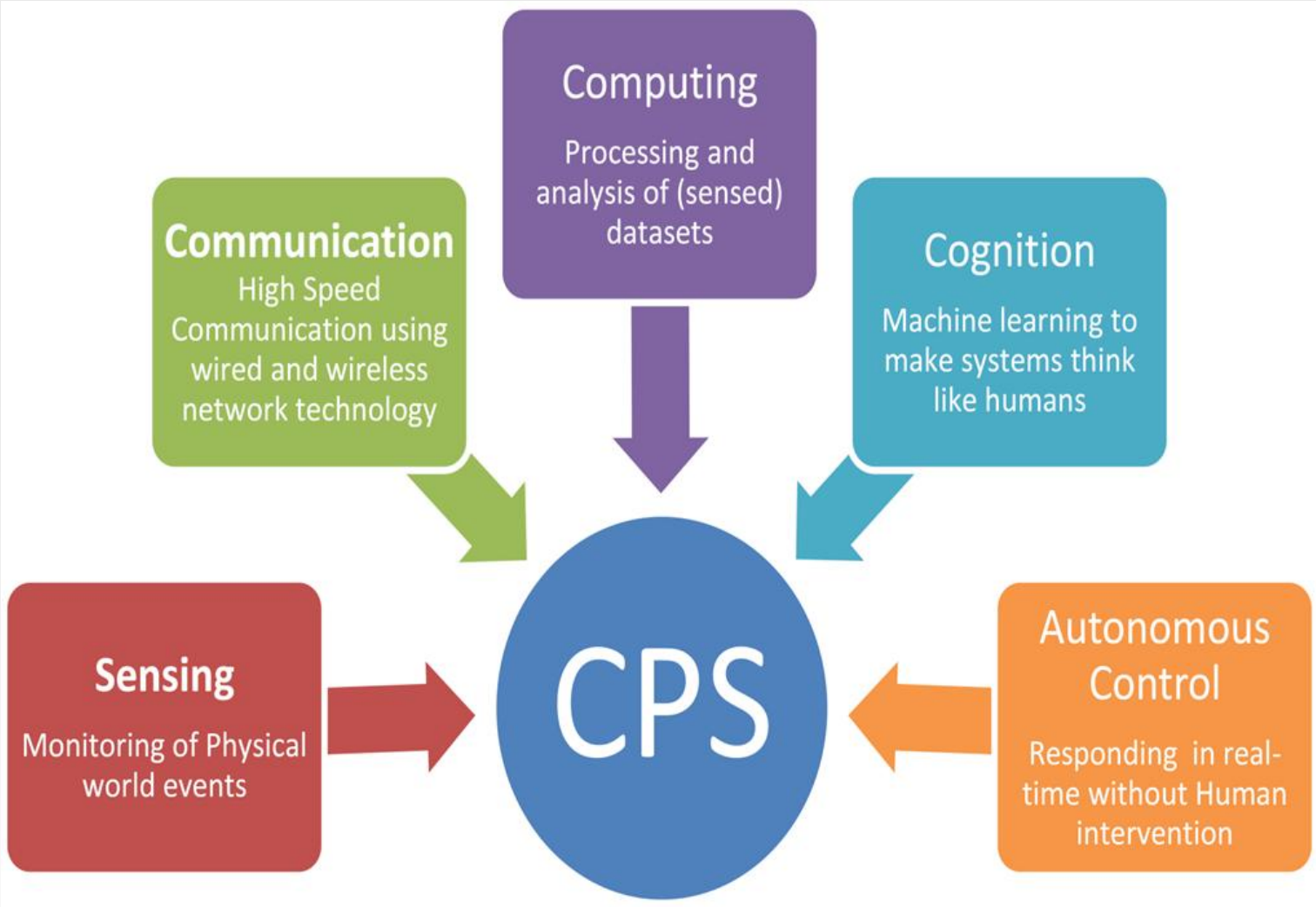
Dr. Bheemarjuna Reddy Tamma

IIT HYDERABAD

CONTENTS

- Background/Motivation
- Wireless Communication Technologies
- Machine-to-Machine Communication
- M2M Architecrures
- Issues in M2M Communicatuon
- Conclusions
- References

CPS Building Blocks



Wireless Communication Technologies

- Communication is the act of exchanging ideas, information, and opinions.
- When we use technical equipment in communicating, it is called *communication technology.*
- When wireless medium is used in any communication technology then it is called Wireless Communication Technology.

Wireless Radio Access Technologies

- Cellular Networks: GSM, UMTS, LTE
- IEEE 802.11, 802.16 (WiMAX), 802.22
- Bluetooth
- ZigBee (802.15.4), UWB
- 6LoWPAN

Types of Communication

- Wireless Communication technology can be used for four distinct types of communication:
  - Human-to-human communication
  - Human-to-machine communication
  - Machine-to-human communication
  - Machine-to-machine communication

M2M sessions will outnumber H2H mobile sessions by a factor of more than 30 to one in 2020.
Source: Forrester

Machine to Machine Communication

Introduction

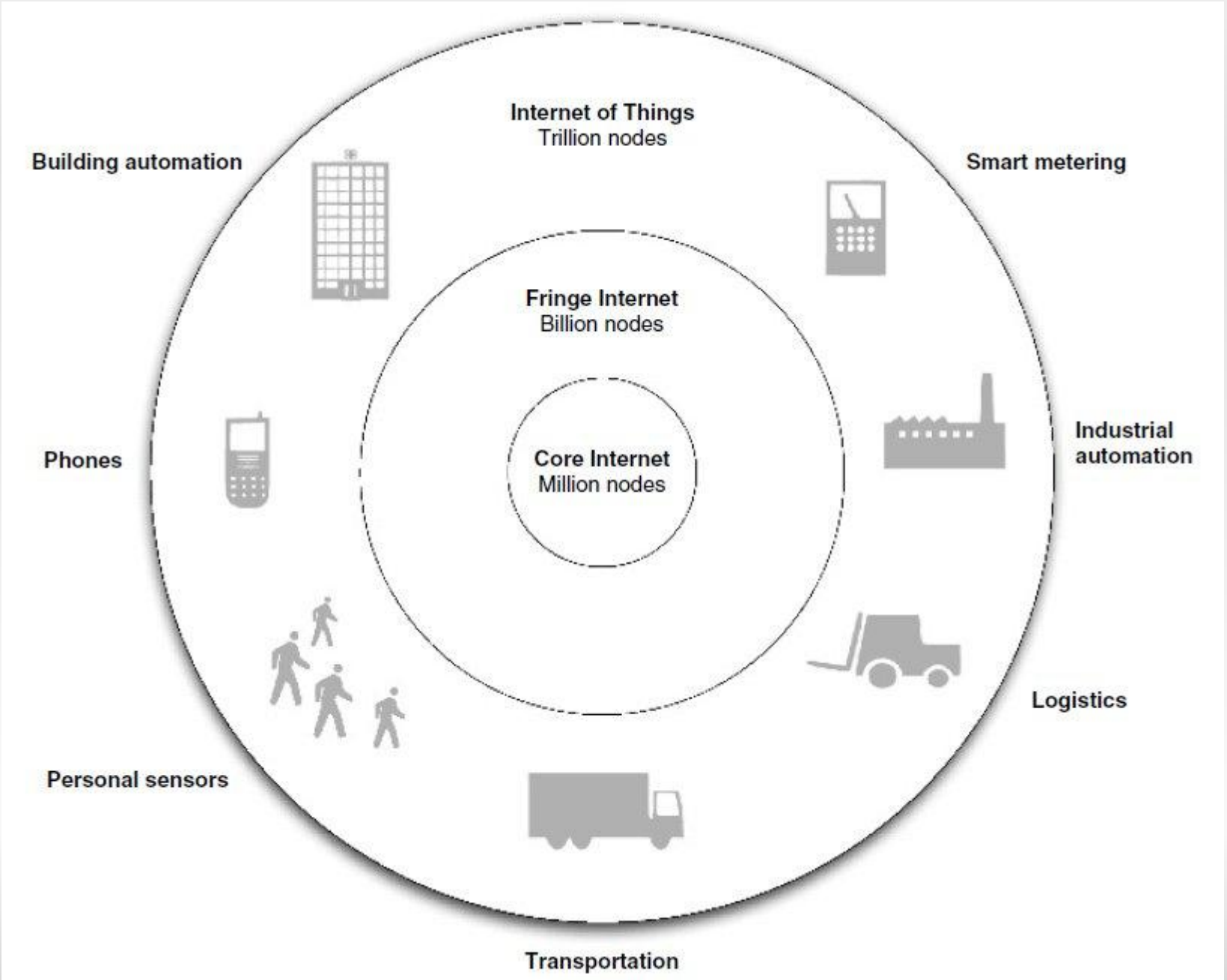
- M2M Definition from Numerex:

  "M2M uses a device (sensor, meter, etc.) to capture an 'event' (temperature, inventory level, etc.), which is relayed through a network (wireless, wired or hybrid) to an application (software program), that translates the captured event into meaningful information (e.g., items need to be restocked)."

  The Internet of 50 Billion Intelligent Devices (Internet of Things)!

- A large number of intelligent machines sharing information and making decisions without direct human intervention.
- Also named Machine Type Communication (MTC) in 3GPP
- Embedded Mobile (Internet)/Internet of Things

Internet of Things Vision



Source: Zach Shelby and Carsten Bormann

M2M Applications

Security

- Surveillance applications, alarms, people tracking

Transportation

- Fleet management, emission control, toll payment

Health care

- e-Health

M2M Applications

Utilities

- Measurement, provisioning and billing of utilities, such as Oil and water

Manufacturing

- Production chain monitoring and automation

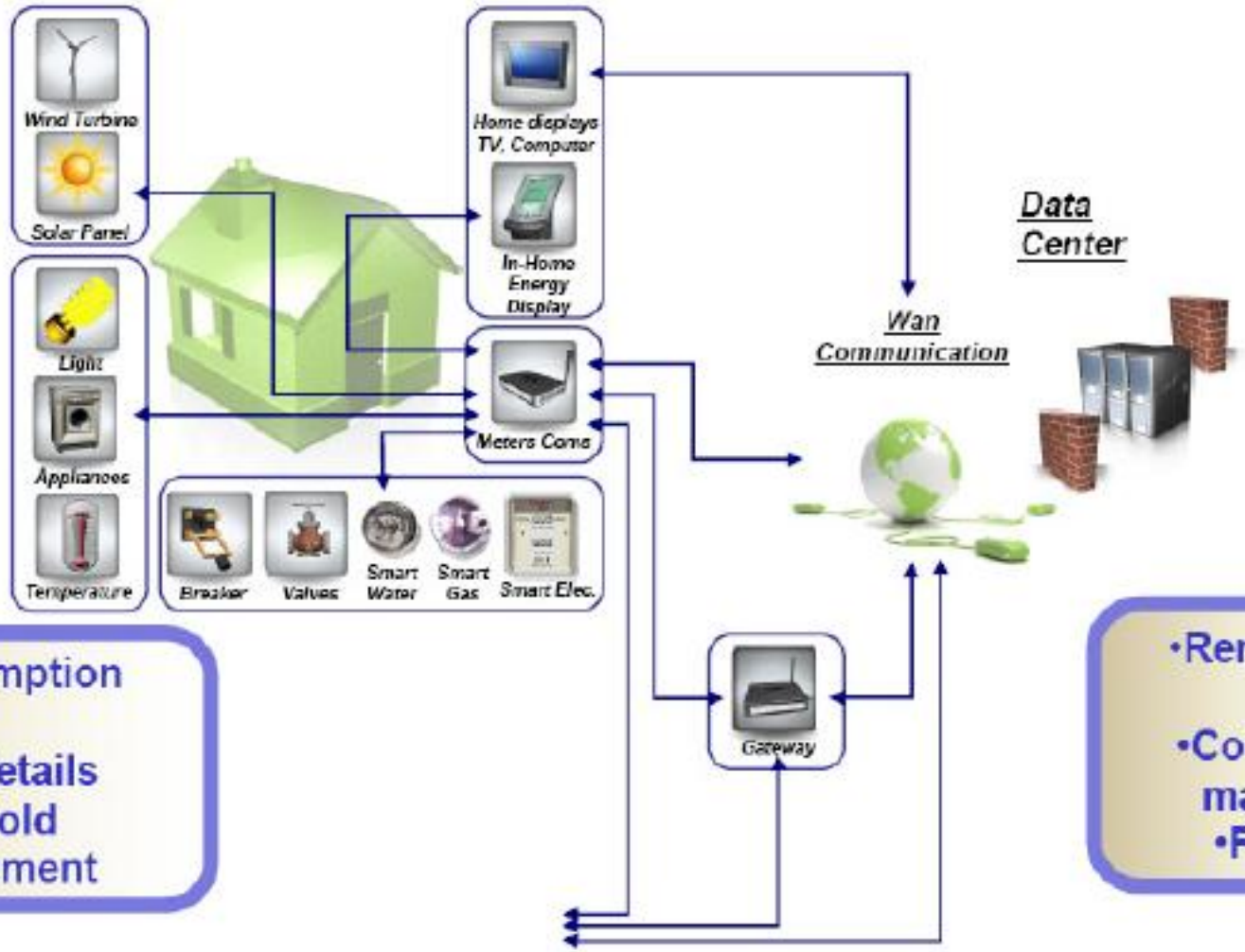
Facility Management

- Home / building / campus automation

Early M2M Prototype Systems

- GPS Navigation System
- Sensor Networks
- Smart Meters

M2M Application – Smart Metering



- Consumption info
- Fault details
- Threshold management

- Remote Meter reading
- Consumption management
- Pricing info

M2M Application – e-Health

Disease management

Ageing independently

Personal fitness

Remote monitoring

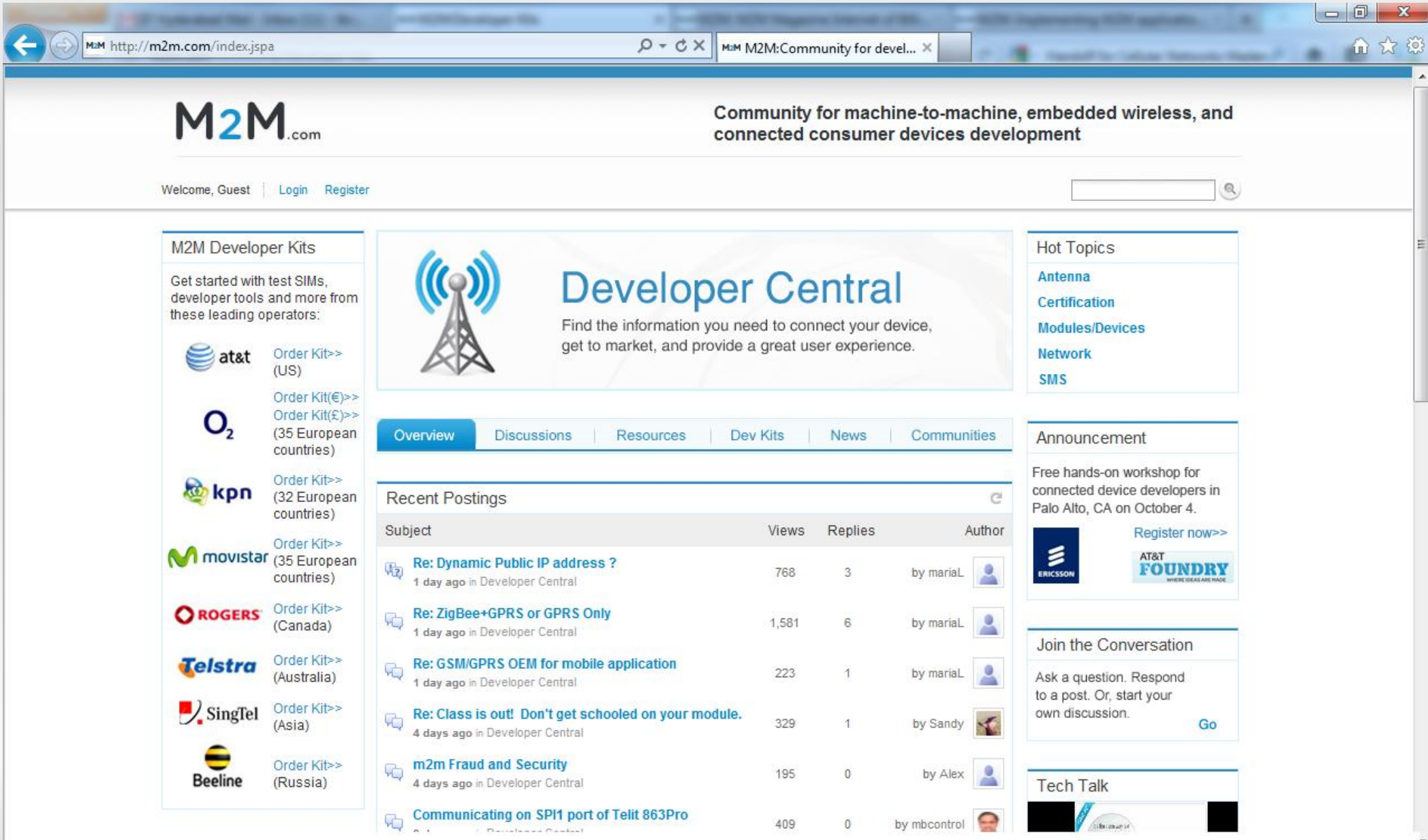
Health Check

On-line health records

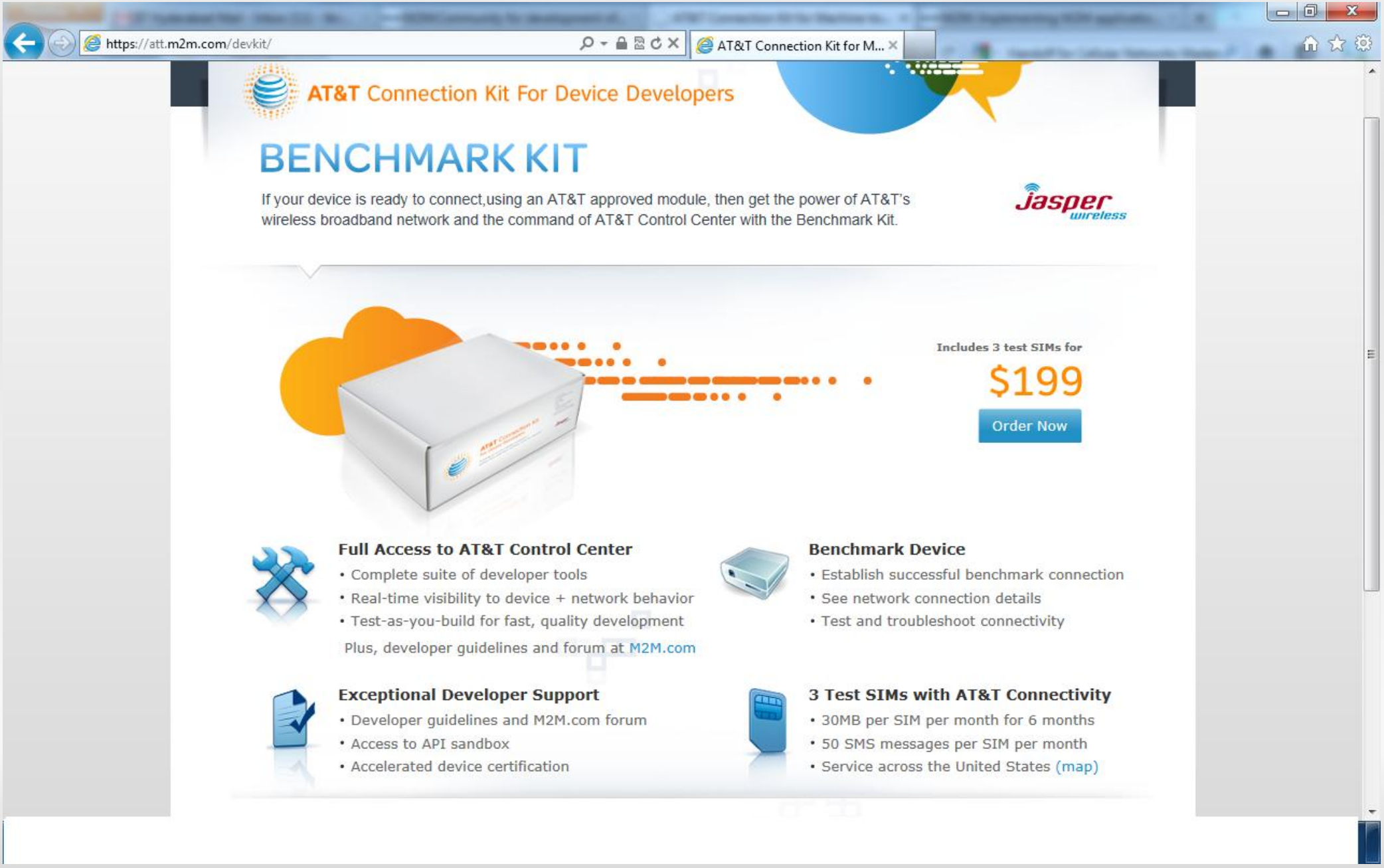
Scheduling appointments

Lifestyle and dietary advice

M2M Community



AT&T M2M Developer Kit



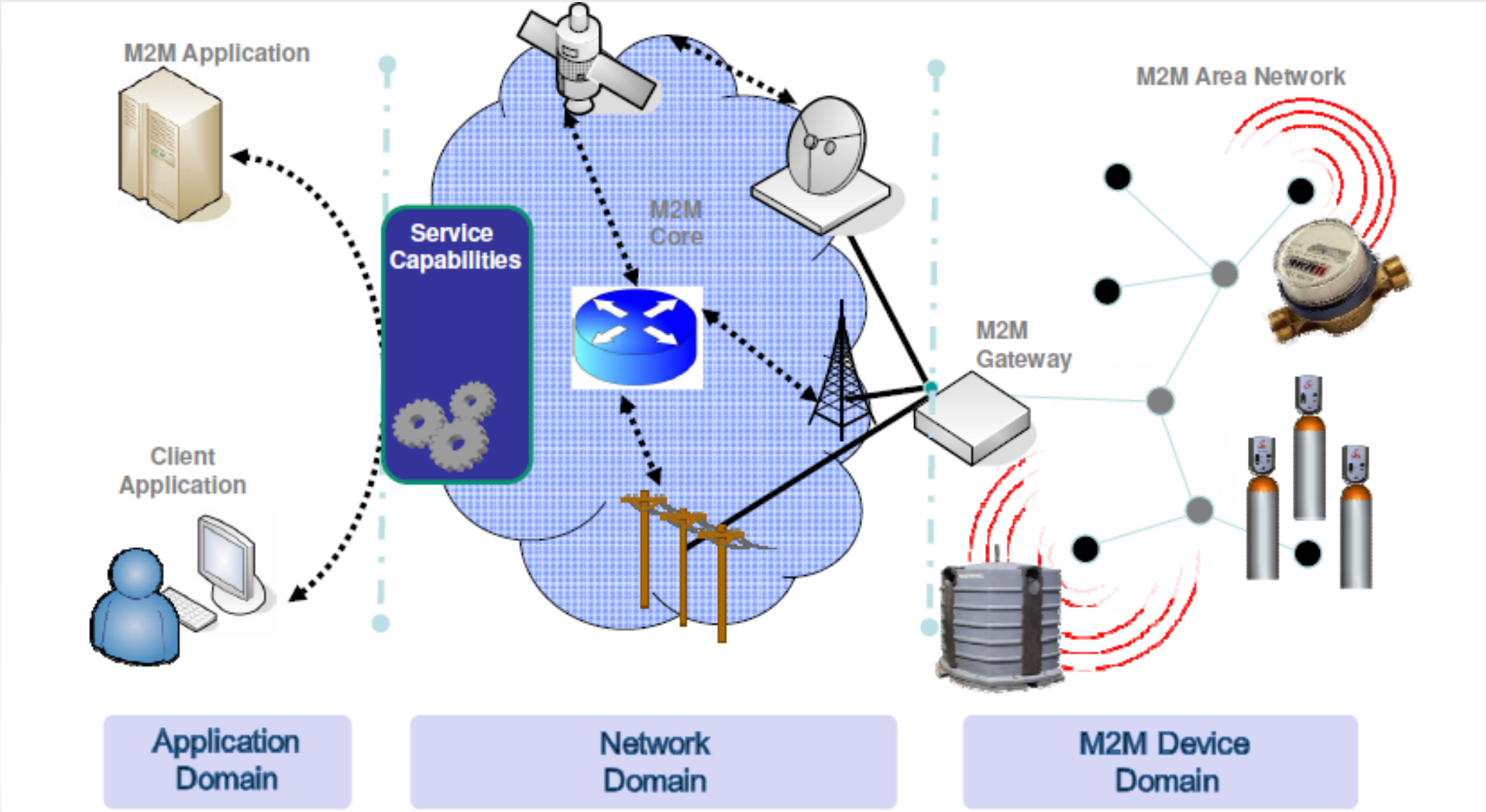
Typical M2M Characteristics

- Low-energy, Low-cost, Low-processing power
- Infrequent and small data transmissions
- Enormous number of MTC nodes
- Two-way communication
- Low-latency and Reliable transmission (QoS)
- No mobility or limited mobility

M2M Architecture

- M2M Architecture consists of three interlinked domains:
  - M2M Device Domain
  - Network Domain
  - Application Domain

M2M Architecture



Architecture …

M2M Device Domain

- M2M Device

  A device capable of replying to request for data contained within that device or capable of transmitting data contained within those devices autonomously

- M2M Area Network

  Provide connectivity between M2M Devices and M2M Gateways

- M2M Gateway

  Use M2M capabilities to ensure M2M Devices inter-working and interconnection to the communication network

Architecture …

Network Domain

- M2M Communication Networks

  Communications between the M2M Gateway(s) and M2M application

  E.g. Access Networks (xDSL, LTE, WiMAX, and WLAN) and Internet

Applications Domain

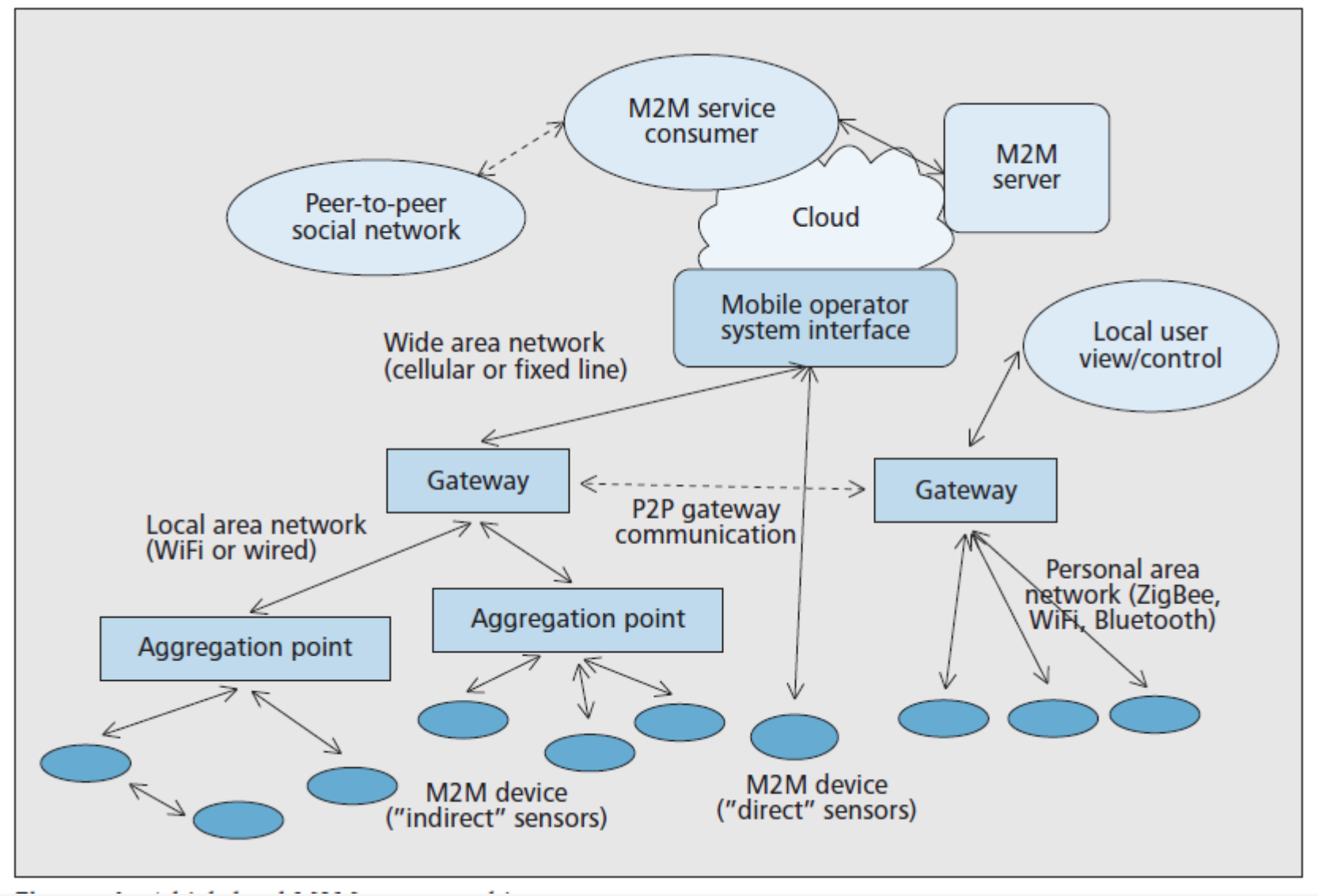
- M2M Applications:

  Contains the middleware layer where data goes through various application services and is used by the specific business-processing engines

M2M System

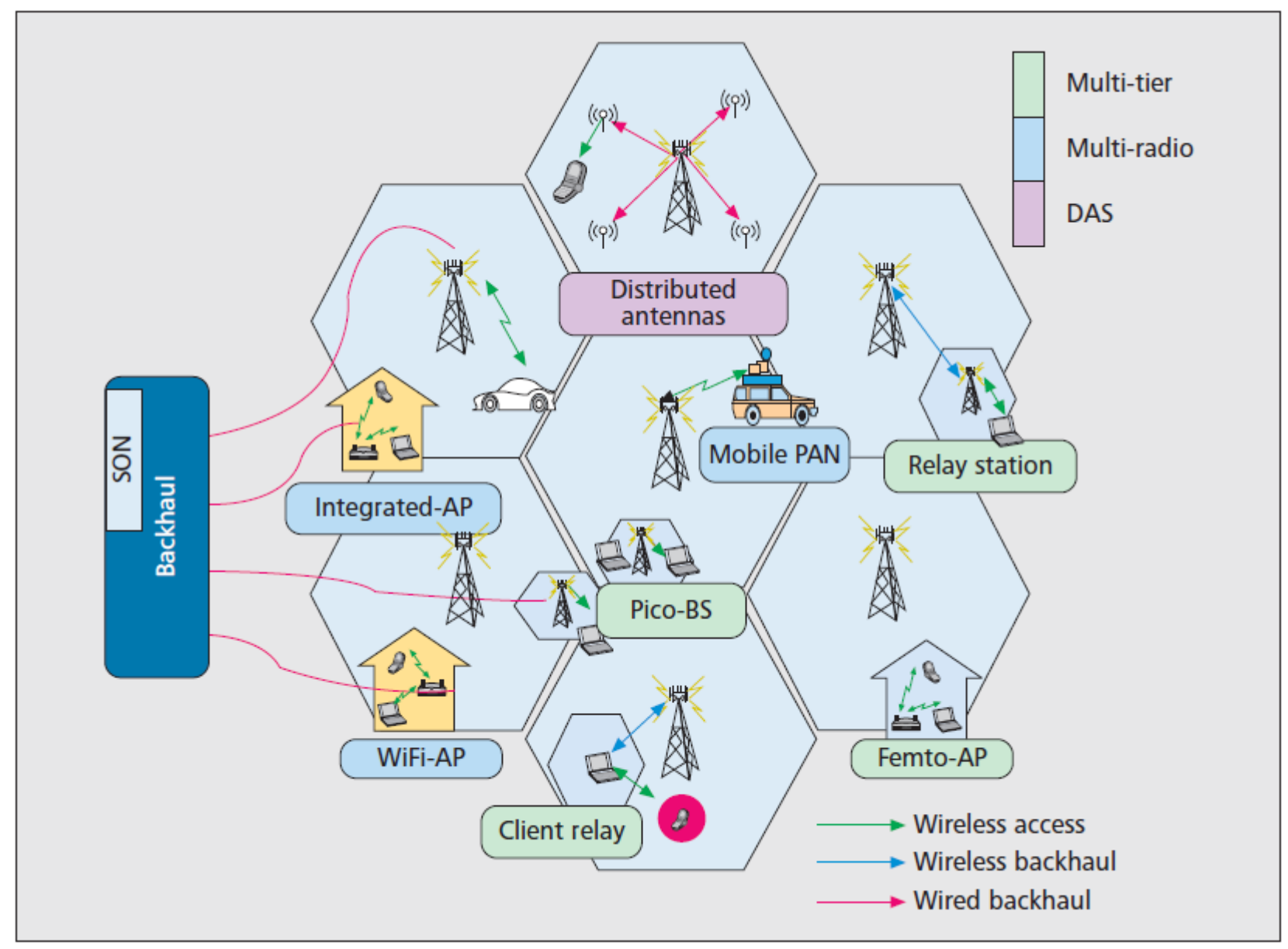
- Sensors: Energy efficient/Self-powered
- Communication Module: Wireline/Wireless (IPv6, VPN)
- Embedded SIMs
- Middleware platforms
  - To give s/w developers an application view of end-to-end M2M data
  - Functionality includes SIM activation, routing, buffering, formatting, managing M2M data
- MNOs (AT&T, O2, Vadafone)
- MVNOs (Wyless, Wireless Logic)
- MVNEs (Aspider Sols): SIM card agreement, IP address management, cost control, fraud management

High Level M2M Architecture



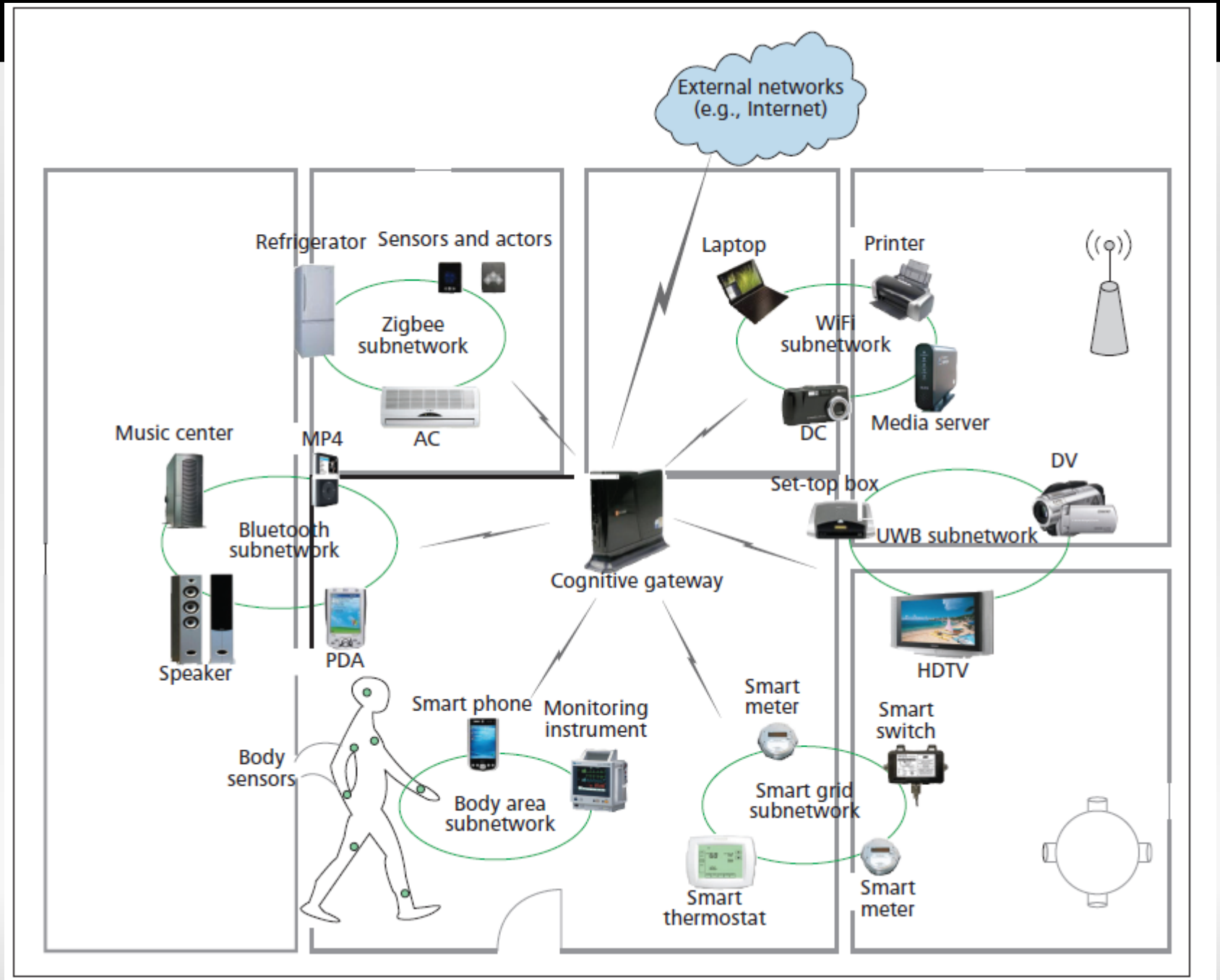
Source: Reference [GWu2011]

Hierarchical M2M Architecture



Source: Reference [IEEE2010]

Home M2M Architecture



Source: Reference [YZhang2011]

Radio Technologies for M2M

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

Source: Reference [YZhang2011]

Issues in M2M

- Naming, Address and routing:

  Alternative addressing solution based on IP addresses should be studied

- Power Saving @ M2M devices:
  - Policies must be developed to save battery power of M2M devices for uninterrupted communication.
  - Optimizing sensing, processing, and transmission activities to save battery power
- Power Saving @ Base Stations
- Scalability of Network Architecture for Trillions of nodes
- Diverse M2M Applications Requirements
- Reliability:

  Reliability in sensing, transmission, and processing must be considered.

- Security:
  - System must be protected from internal and external attacks.
  - Requirements: Confidentiality, Integrity, Authentication, Access Control, Privacy, Availability
- Service levels and QoS

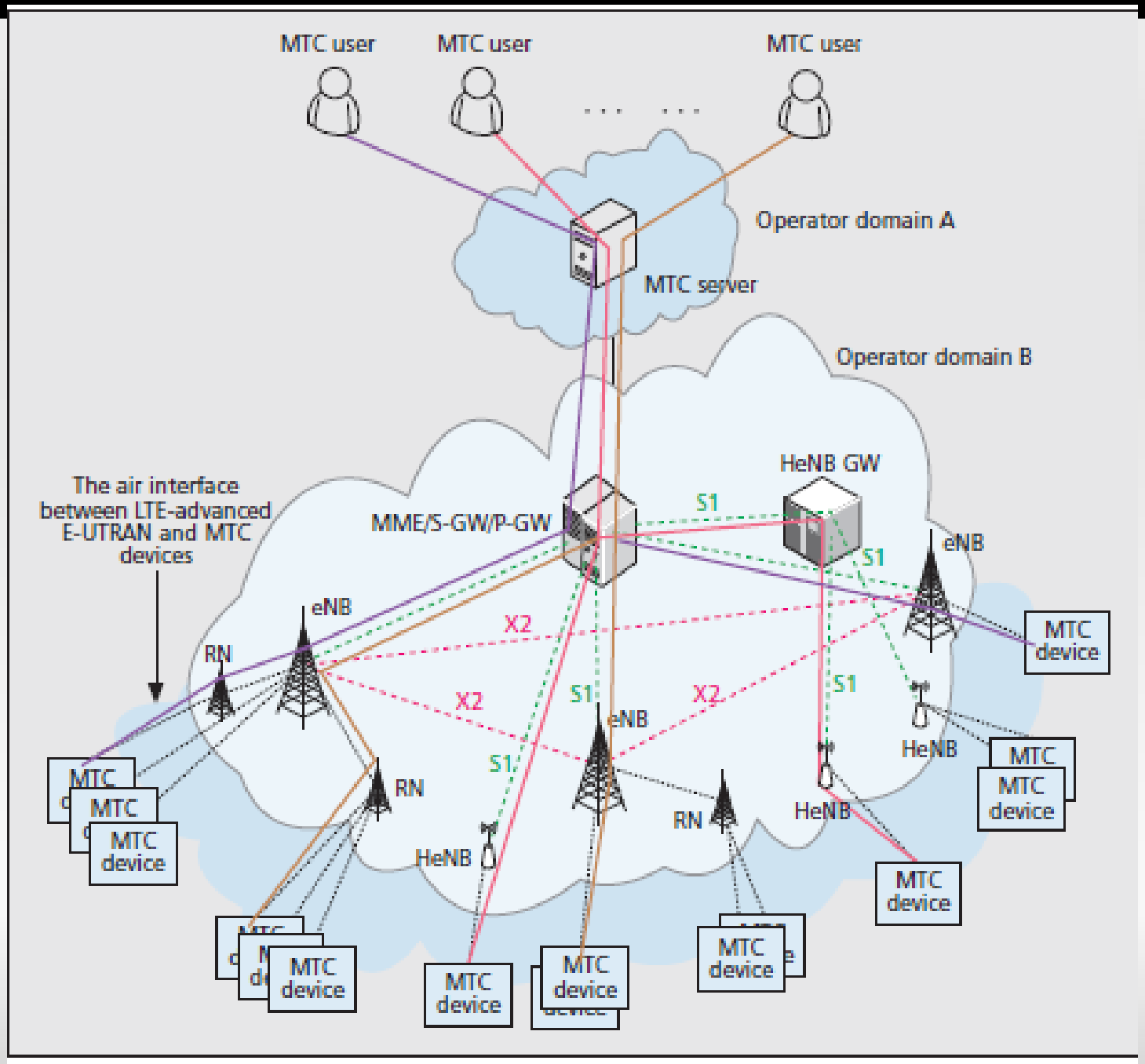
  New QoS profiles needs to be defined

RAT Optimizations for M2M

Features	Applications	Standards impacts							
		Sleep and idle mode	Mobility management	Link adaptation	BW request & Allocation	HARQ and ARQ	Frame structure	Network entry	Cooperation
Mass device transmission	Security Metering Tracking		√	√	√	√	√	√	√
High reliability	Health Security	√	√	√	√	√	√		√
Access priority	Health Remote maint & control	√	√		√	√	√	√	
Very low power	Tracking Remote maint & control	√	√	√	√	√	√	√	√
Small data burst	Metering Remote maint & control	√				√			
Low/no mobility	Metering	√	√	√	√			√	√
Monitoring and security	Vehicular Payment	√					√	√	

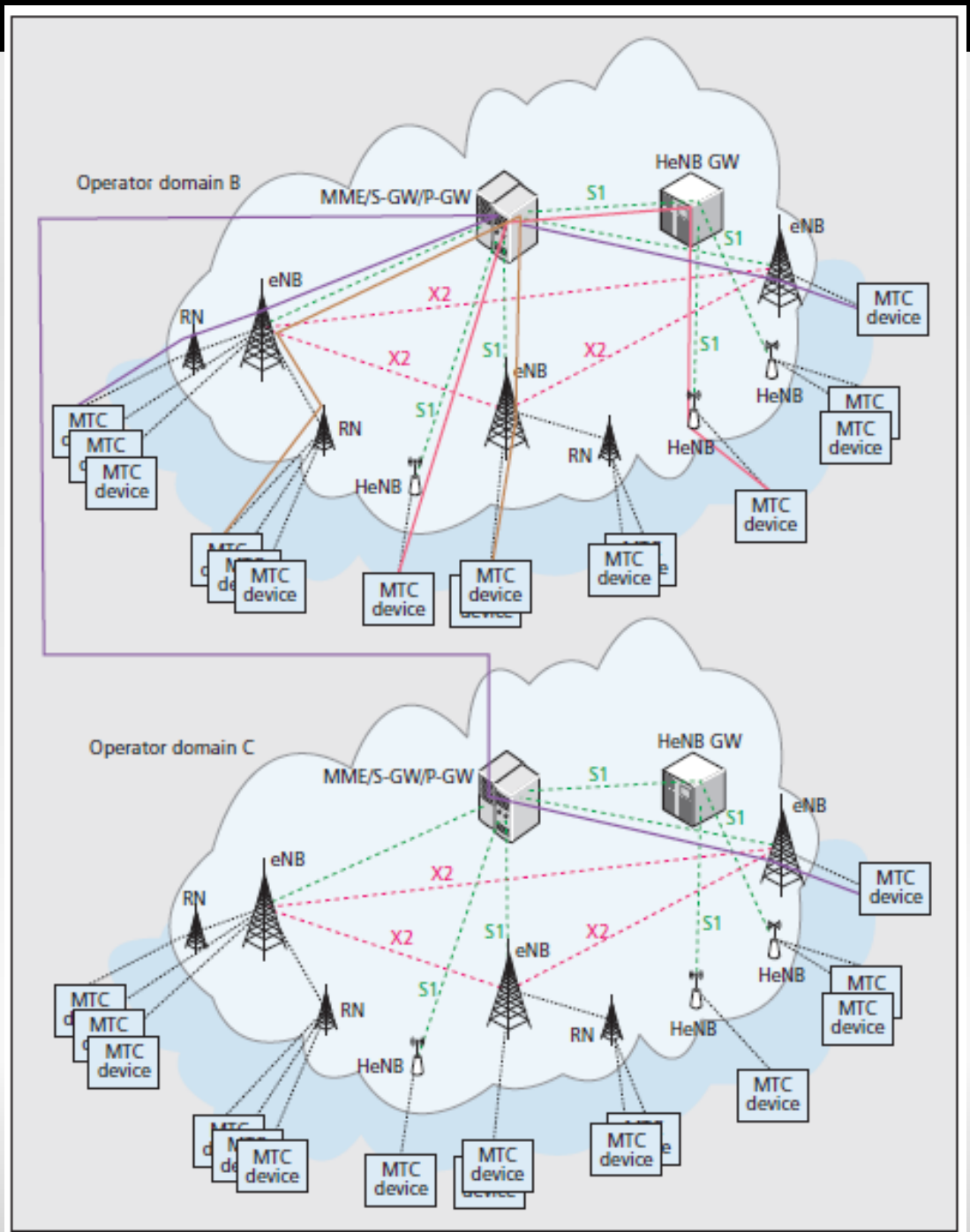
Source: Reference [GWu2011]

3GPP M2M Architecture -- 1



Source: [SLien2011]

3GPP M2M Architecture -- 2



Source: [SLien2011]

LTE for M2M?

Are sophisticated link adaption techs required?	• MIMO, Beam forming, Adaptive Modulation, HARQ, CoMP Tx for Higher Data Rate
Are there enough resources on control channel?	• 10 MTCs per sub-frame in PDCCH • New Frame structure for M2M?
Random access channel contentions!	• Enormous no of MTC Devices • BO scheme/ Separate resources
Energy, Complexity, QoS, Mobility, Reliability	• These become more critical & different issues compared to UEs of H2H

SDO	M2M development
3GPP	**Release 10:** identify requirements and optimize radio and network for features such as low power, congestion and overload control, identifiers, addressing, subscription control and security. **Release 11 and beyond:** network improvements for device to device communication, M2M gateway, enhancements for M2M group and co-located M2M devices, network selection and steering, service requirements and optimizations.
ETSI	**M2M network architecture:** define functional and behavioral requirements of each network element to provide an end-to-end view.
GSMA	**GSM operation for M2M:** define a set of GSM based embedded modules that address operational issues, such as module design, radio interface, remote management, UICC provisioning and authentication, and basic elements costs. Also define use-cases in vertical markets: health, utilities, automotive, and consumer devices.
IEEE	**802.16p (WiMAX):** optimize air interface for low power, mass device transmission, small bursts, and device authentication. Future topics: M2M gateway, co-operative M2M networks, advanced M2M features **802.11 (WiFi):** update air interface to enable use of sub-GHz spectrum **802.15.4 (ZigBee):** air interface optimization for smart grid networks
WiMAX Forum	**Network system architecture specification:** define usages, deployment models with low OPEX, functional requirements based on IEEE 802.16 protocols, and performance guidelines for end-to-end M2M system.
WFA	**Smart grid task group:** promote the adoption of Wi-Fi within the smart grid through marketing initiatives, government and industry engagement, and technical/certification programs **Healthcare task group:** maintain Wi-Fi as the preferred wireless access technology and increase adoption in the Home and Hospital Healthcare market segment.
OMA	**Device manageability:** define requirements for the gateway managed object
TIA	**M2M SW architecture TR50:** develop and maintain access agnostic interface standards for monitoring and bi-directional communication of events and information between smart devices and other devices, applications or networks.
CCSA NITS	**CCSA TC10:** focus on pervasive networks, including general requirements, applications, networking, sensing and related short range RF connectivity. **NITS WGSN:** focus on sensor network interface and data format, ID and security, vertical applications including airport and smart buildings.

Source: Reference [GWu2011]

Conclusions

- M2M Solutions ⟹ Internet of Things (CPS)
- Urgently needs standardization of various RATs for enabling mass scale deployments
- M2M deployments are another source of revenue for Network Operators, OEMs, IT industry
- Energy, QoS, Security, Cost are main factors

References

- [YZhang2011] Yan Zhang et. al., “Home M2M Networks: Architectures, Standards, and QoS Improvement”, *IEEE Communication Magazine*, April 2011.
- [GWu2011] Geng Wu et. al., “M2M: From Mobile to Embedded Internet”, *IEEE Communication Magazine*, April 2011.
- [IEEE2010] IEEE C80216-10_0016r1, “Future 802.16 Network: Challenges and Possibilities,” March 2010.
- [LTEM2M] Yu Chen, Wei Wang, “Machine-to-Machine communication in LTE-A”, 2010.
- [SLien2011] S. Lien, K. Chen, and Y. Lin, “Toward Ubiquitous Massive Accesses in 3GPP Machine-to-Machine Communications”, *IEEE Communication Magazine*, April 2011.