Automação Predial com IoT – Parte B - Smart/Wireless

Tópicos em Engenharia 2020.2

Smart Cities, Building Automation, IoT, nZEB, ESP32,...

Adolfo Bauchspiess
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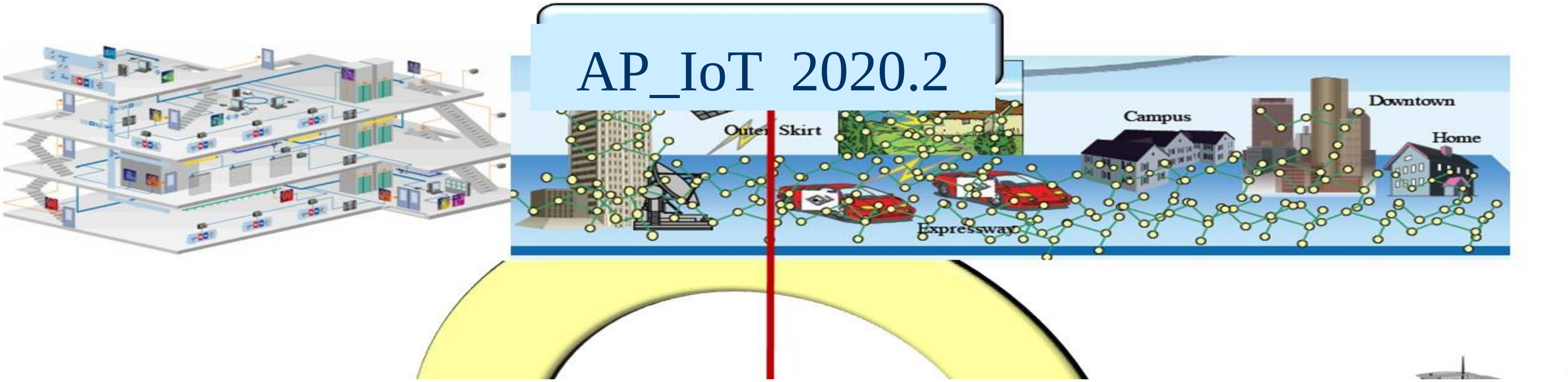
AP_IoT 2020.2

Conteúdo

Excerpt of Selected Papers
Periodicos.CAPES - 2021

1 – Verma et at. 2019 Sensing, Controlling, and IoT Infrastructure in Smart Building: A Review

2 – Martín-Lopo, 2020 A literature review of IoT energy platforms aimed at end users

3 –Patel et al. 2019 Simulators, Emulators, and Test-beds for Internet of Things: A Comparison,

4 - Omoniwa et al.2019 Fog/Edge Computing-Based IoT (FECIoT):Architecture, Applications, and Research Issues,

4 - Christopoulos et al. 2016 Building Automation Systems in the World of Internet of Things

5 - Yïci, et al. 2020 Survey of Internet of Things (IoT) Infrastructures for Building Energy Systems

6 - Sobin. 2020 A Survey on Architecture, Protocols and Challenges in IoT

7 - Minoli et al. 2017 IoT Considerations, Requirements, and Architectures for Smart Buildings—Energy Optimization and Next-Generation Building Management Systems

Sensing, Controlling, and IoT Infrastructure in Smart Building: A Review

Verma et al. IEEE SENSORS JOURNAL, VOL. 19, NO. 20, OCTOBER 15, 2019

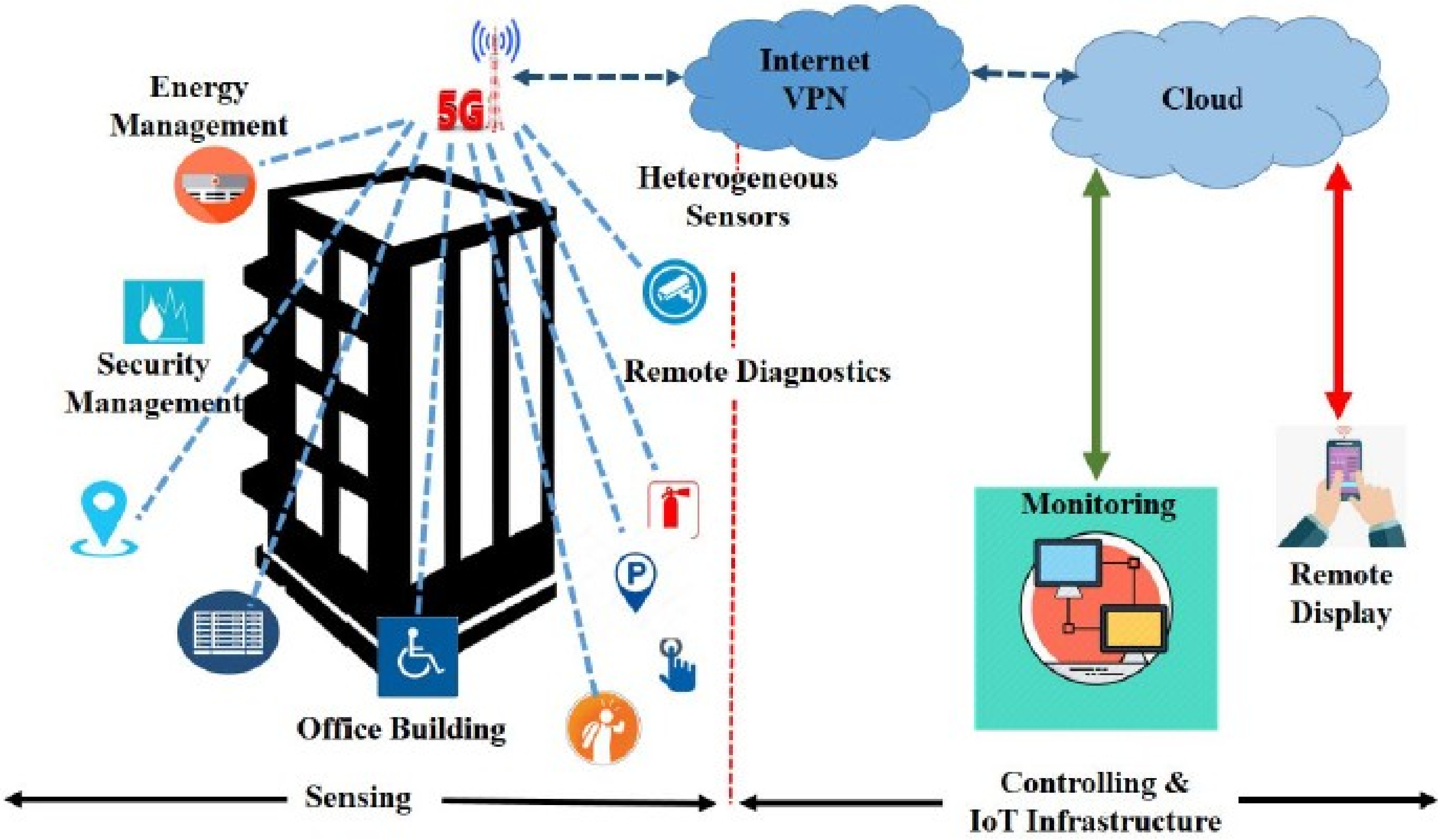

Fig. 1. Modified smart buildings with intelligent features [7], [8].

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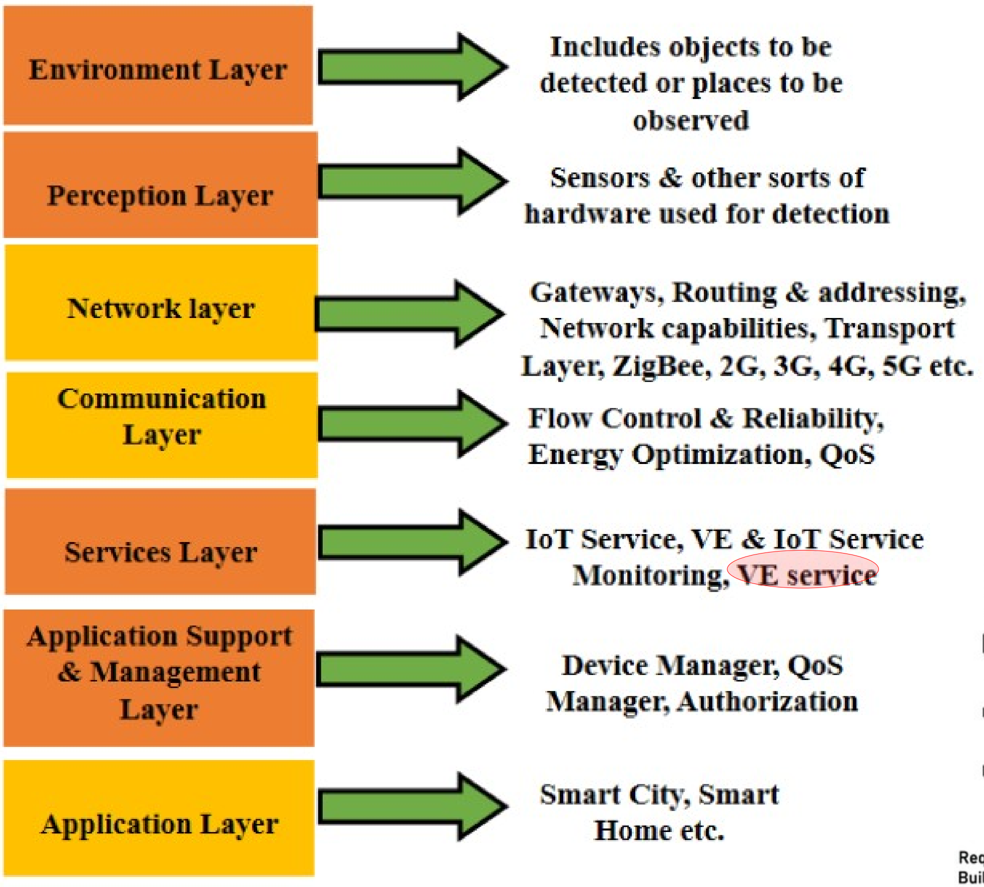
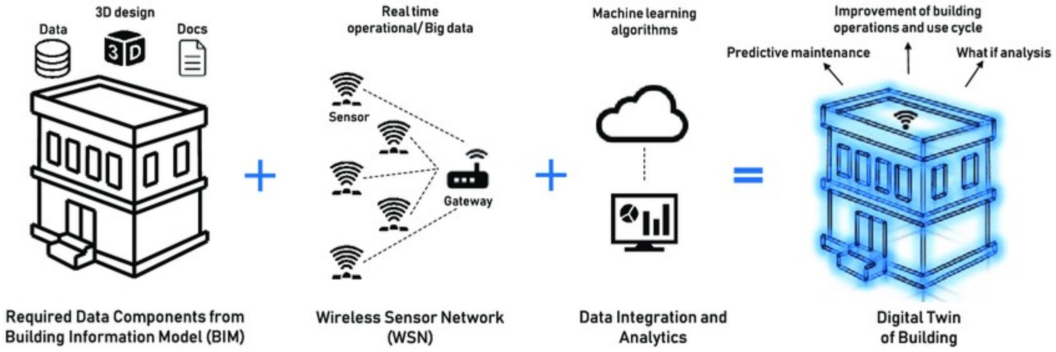


Environment Layer	Includes objects to be detected or places to be observed
Perception Layer	Sensors & other sorts of hardware used for detection
Network layer	Gateways, Routing & addressing, Network capabilities, Transport Layer, ZigBee, 2G, 3G, 4G, 5G etc.
Communication Layer	Flow Control & Reliability, Energy Optimization, QoS
Services Layer	IoT Service, VE & IoT Service Monitoring, VE service
Application Support & Management Layer	Device Manager, QoS Manager, Authorization
Application Layer	Smart City, Smart Home etc.

Fig. 2. 7-layer architecture of IoT Infrastructure [7], [8].

Virtual Entity
x
Digital Twin



https://www.researchgate.net/figure/Essential-components-to-create-a-digital-twin-of-building-and-difference-with-BIM_fig5_336375033

Sensing, Controlling, and IoT Infrastructure in Smart Building: A Review

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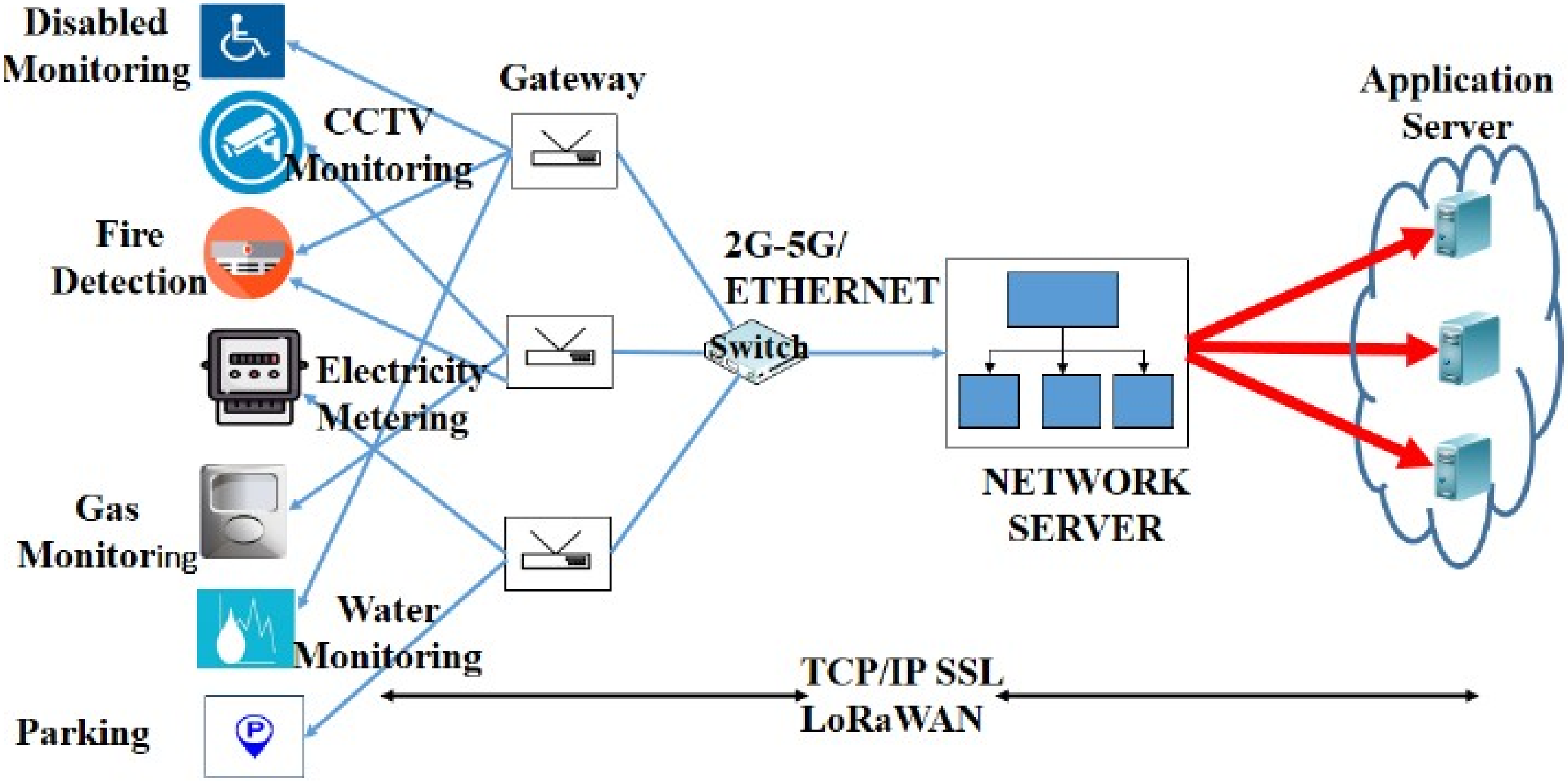


Fig. 3. LoRaWAN Architecture [10]–[14].

Sensing, Controlling, and IoT Infrastructure in Smart Building: A Review

Verma et al. IEEE SENSORS JOURNAL, VOL. 19, NO. 20, OCTOBER 15, 2019

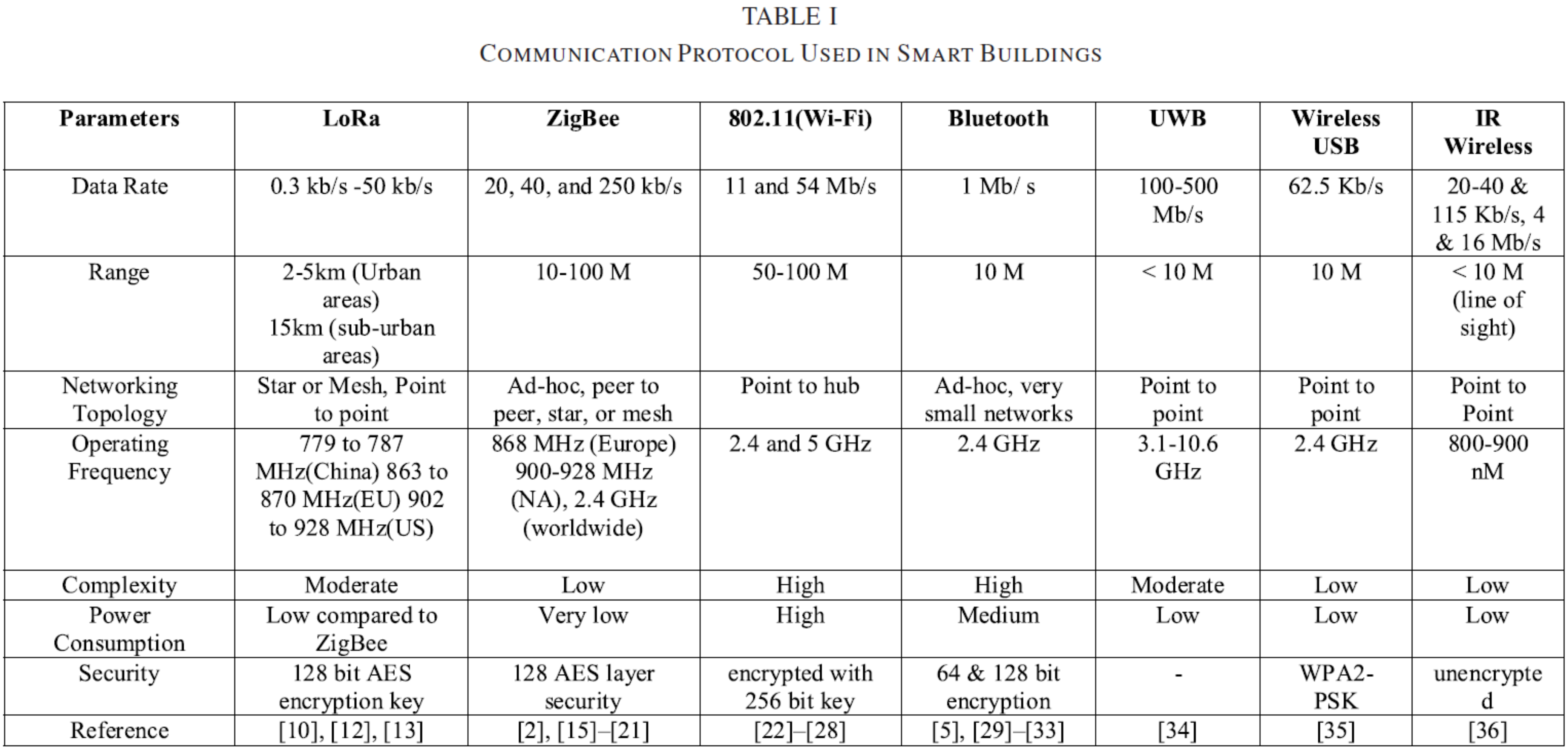
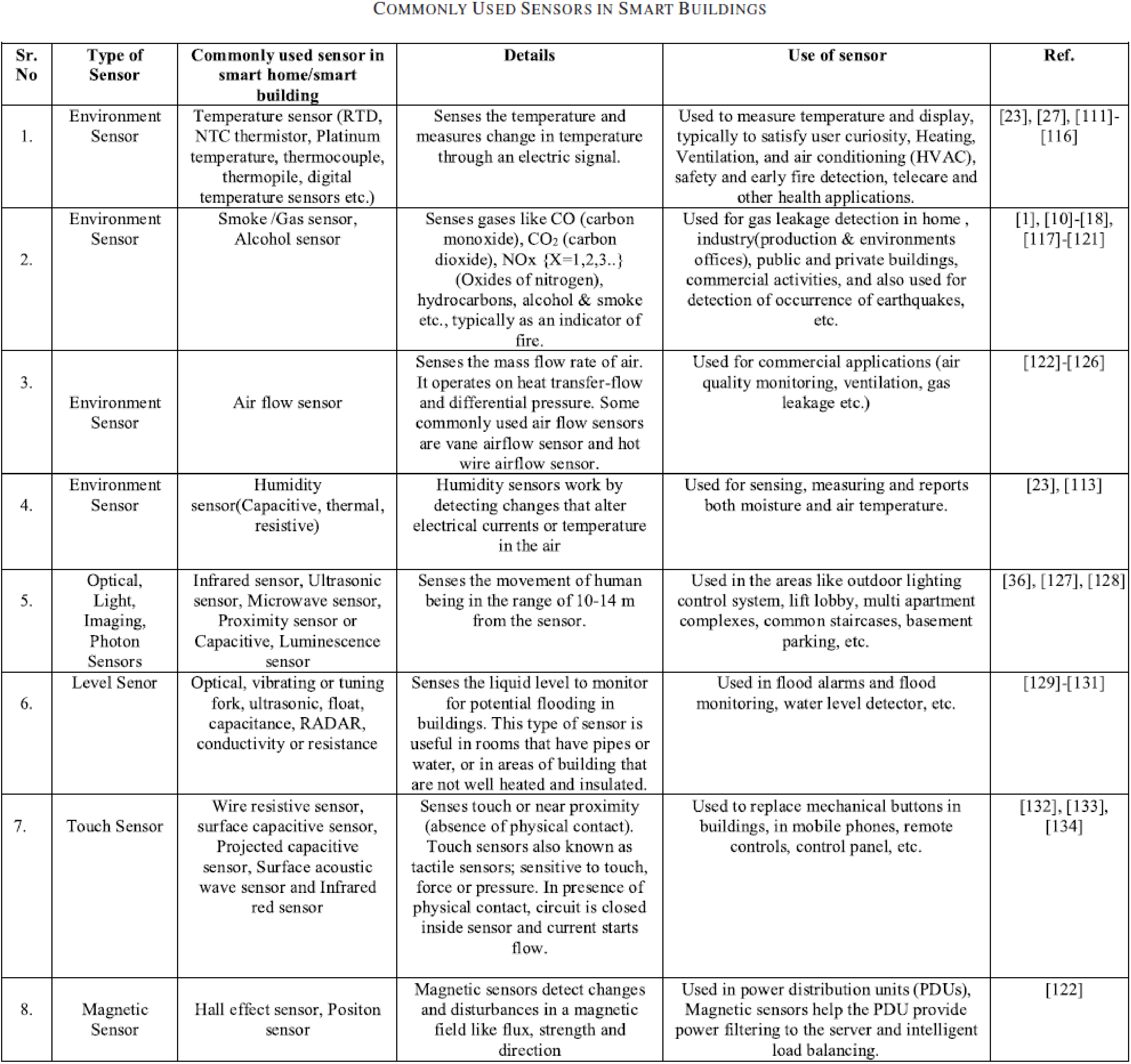


TABLE I

COMMUNICATION PROTOCOL USED IN SMART BUILDINGS

Parameters	**LoRa**	**ZigBee**	**802.11(Wi-Fi)**	**Bluetooth**	**UWB**	**Wireless USB**	**IR Wireless**
Data Rate	0.3 kb/s -50 kb/s	20, 40, and 250 kb/s	11 and 54 Mb/s	1 Mb/ s	100-500 Mb/s	62.5 Kb/s	20-40 & 115 Kb/s, 4 & 16 Mb/s
Range	2-5km (Urban areas) 15km (sub-urban areas)	10-100 M	50-100 M	10 M	< 10 M	10 M	< 10 M (line of sight)
Networking Topology	Star or Mesh, Point to point	Ad-hoc, peer to peer, star, or mesh	Point to hub	Ad-hoc, very small networks	Point to point	Point to point	Point to Point
Operating Frequency	779 to 787 MHz(China) 863 to 870 MHz(EU) 902 to 928 MHz(US)	868 MHz (Europe) 900-928 MHz (NA), 2.4 GHz (worldwide)	2.4 and 5 GHz	2.4 GHz	3.1-10.6 GHz	2.4 GHz	800-900 nM
Complexity	Moderate	Low	High	High	Moderate	Low	Low
Power Consumption	Low compared to ZigBee	Very low	High	Medium	Low	Low	Low
Security	128 bit AES encryption key	128 AES layer security	encrypted with 256 bit key	64 & 128 bit encryption	-	WPA2-PSK	unencrypte d
Reference	[10], [12], [13]	[2], [15]–[21]	[22]–[28]	[5], [29]–[33]	[34]	[35]	[36]

Verma et al. 2019



COMMONLY USED SENSORS IN SMART BUILDINGS

Sr. No	Type of Sensor	Commonly used sensor in smart home/smart building	Details	Use of sensor	Ref.
1.	Environment Sensor	Temperature sensor (RTD, NTC thermistor, Platinum temperature, thermocouple, thermopile, digital temperature sensors etc.)	Senses the temperature and measures change in temperature through an electric signal.	Used to measure temperature and display, typically to satisfy user curiosity, Heating, Ventilation, and air conditioning (HVAC), safety and early fire detection, telecare and other health applications.	[23], [27], [111]-[116]
2.	Environment Sensor	Smoke /Gas sensor, Alcohol sensor	Senses gases like CO (carbon monoxide), CO_2 (carbon dioxide), NOx {X=1,2,3..} (Oxides of nitrogen), hydrocarbons, alcohol & smoke etc., typically as an indicator of fire.	Used for gas leakage detection in home , industry(production & environments offices), public and private buildings, commercial activities, and also used for detection of occurrence of earthquakes, etc.	[1], [10]-[18], [117]-[121]
3.	Environment Sensor	Air flow sensor	Senses the mass flow rate of air. It operates on heat transfer-flow and differential pressure. Some commonly used air flow sensors are vane airflow sensor and hot wire airflow sensor.	Used for commercial applications (air quality monitoring, ventilation, gas leakage etc.)	[122]-[126]
4.	Environment Sensor	Humidity sensor(Capacitive, thermal, resistive)	Humidity sensors work by detecting changes that alter electrical currents or temperature in the air	Used for sensing, measuring and reports both moisture and air temperature.	[23], [113]
5.	Optical, Light, Imaging, Photon Sensors	Infrared sensor, Ultrasonic sensor, Microwave sensor, Proximity sensor or Capacitive, Luminescence sensor	Senses the movement of human being in the range of 10-14 m from the sensor.	Used in the areas like outdoor lighting control system, lift lobby, multi apartment complexes, common staircases, basement parking, etc.	[36], [127], [128]
6.	Level Senor	Optical, vibrating or tuning fork, ultrasonic, float, capacitance, RADAR, conductivity or resistance	Senses the liquid level to monitor for potential flooding in buildings. This type of sensor is useful in rooms that have pipes or water, or in areas of building that are not well heated and insulated.	Used in flood alarms and flood monitoring, water level detector, etc.	[129]-[131]
7.	Touch Sensor	Wire resistive sensor, surface capacitive sensor, Projected capacitive sensor, Surface acoustic wave sensor and Infrared red sensor	Senses touch or near proximity (absence of physical contact). Touch sensors also known as tactile sensors; sensitive to touch, force or pressure. In presence of physical contact, circuit is closed inside sensor and current starts flow.	Used to replace mechanical buttons in buildings, in mobile phones, remote controls, control panel, etc.	[132], [133], [134]
8.	Magnetic Sensor	Hall effect sensor, Positon sensor	Magnetic sensors detect changes and disturbances in a magnetic field like flux, strength and direction	Used in power distribution units (PDUs), Magnetic sensors help the PDU provide power filtering to the server and intelligent load balancing.	[122]

A literature review of IoT energy platforms aimed at end users

Martín-Lopo et al. Computer Networks 171 (2020) 107101

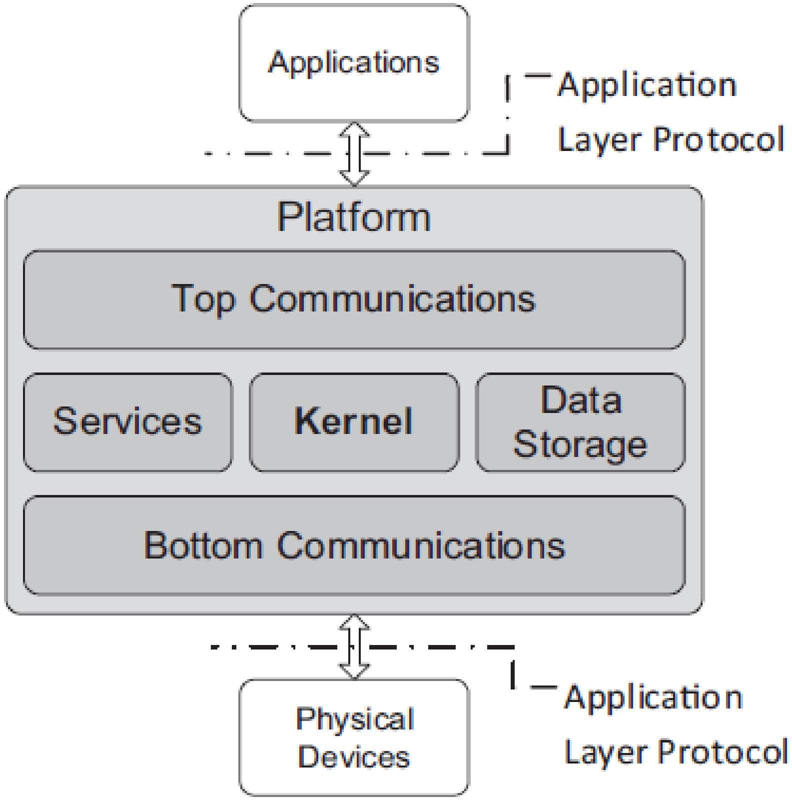


Fig. 1. Building blocks of an energy platform cloud architecture.

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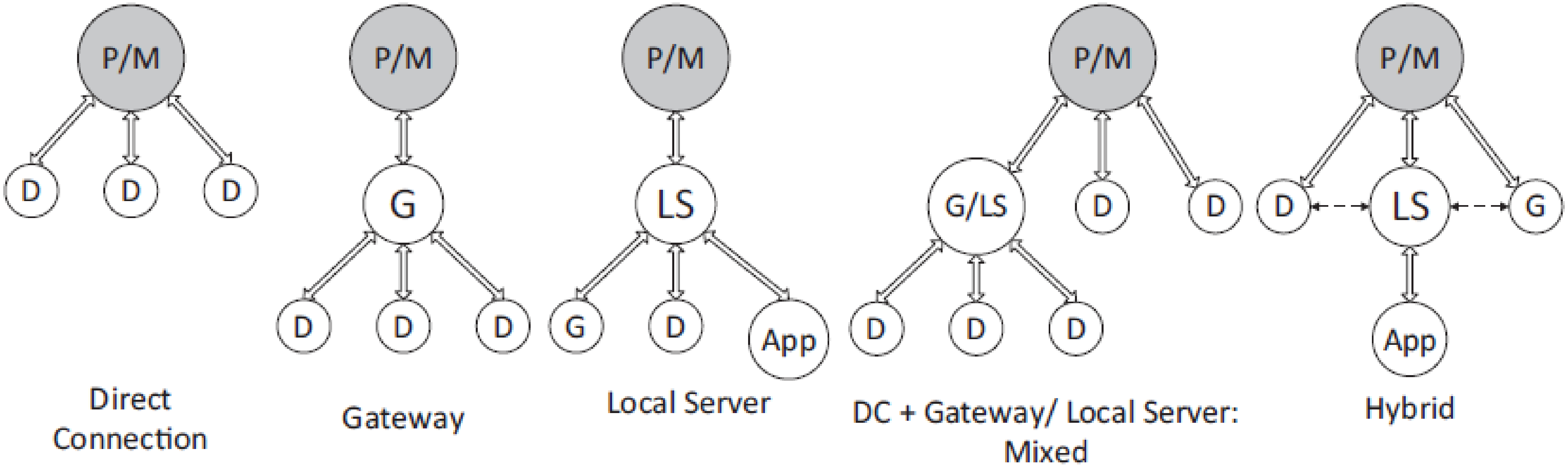

Fig. 2. Bottom topologies identified to connect physical devices (D) to a platform (P) or middleware (M). G refers to gateway and LS to local server. In some cases, the smartphone or desktop applications (App) can work within the local network (i.e., without Internet connection).

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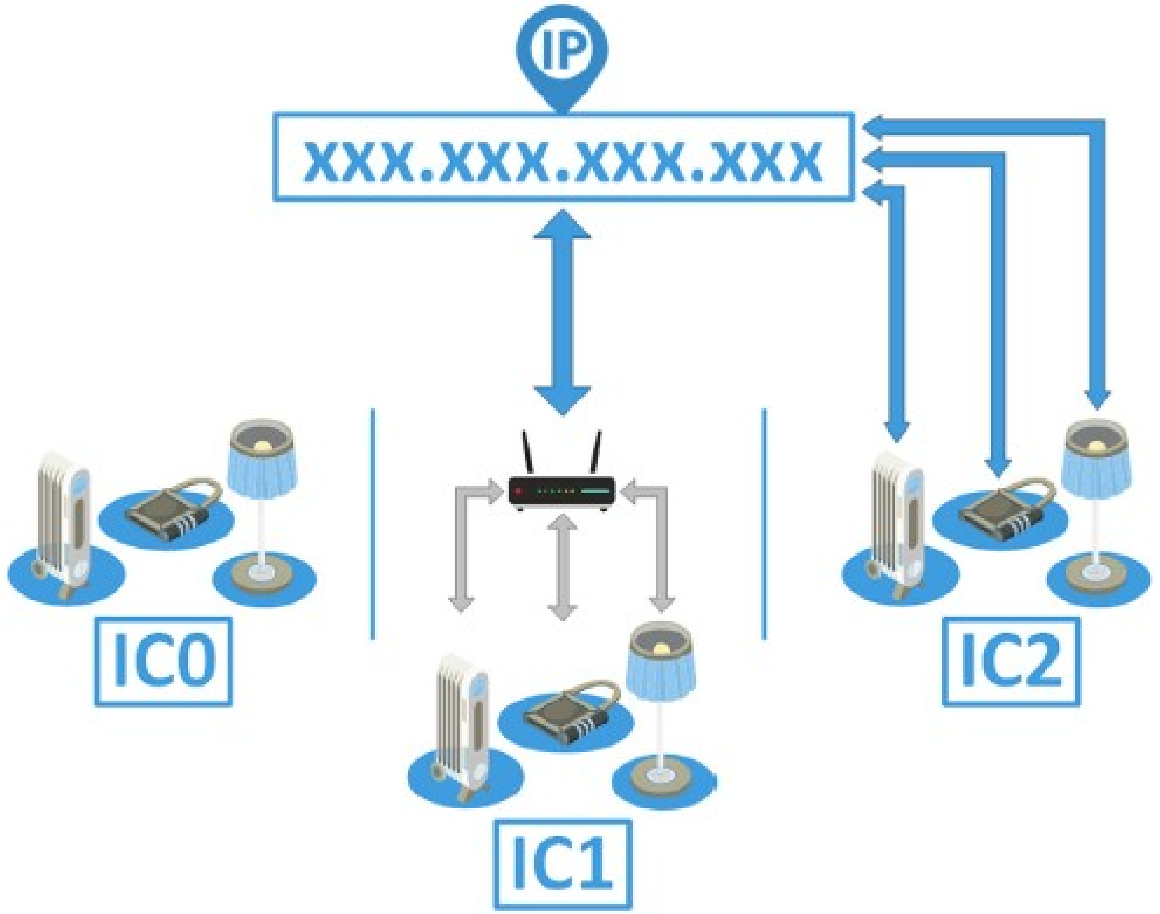

Fig. 3. Internet connectivity tiers. IC0: Systems that do not have access to the Internet or do not handle “Things”. IC1: Platforms that handle Internet communications, but only some devices handle IP-based communications, providing gateway services for the rest of them. IC2: Platforms that handle Internet communications, and every device handles IP-based communications.

A literature review of IoT energy platforms aimed at end users

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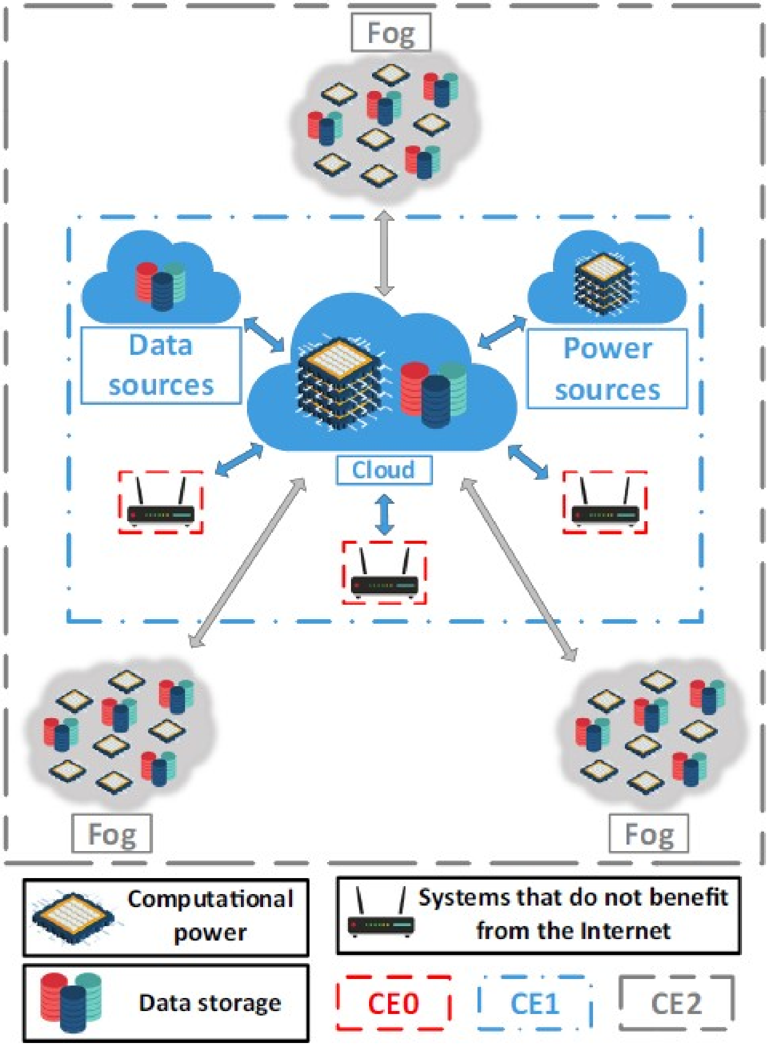

Fig. 4. Connectivity exploitation tiers.
CE0: Platforms that do not benefit from being connected to the Internet beyond remote access.
CE1: Platforms that benefit from being connected because they have access to additional computational power and/or new data sources.
CE2: Platforms that address the limitations of previous levels in terms of latency, bandwidth efficiency, load balancing, resiliency, and security (e.g., by distributing load and information). The icon enclosed within CE0 bounds represents a full sensor/actuator network together with its local server (if the latter exists).

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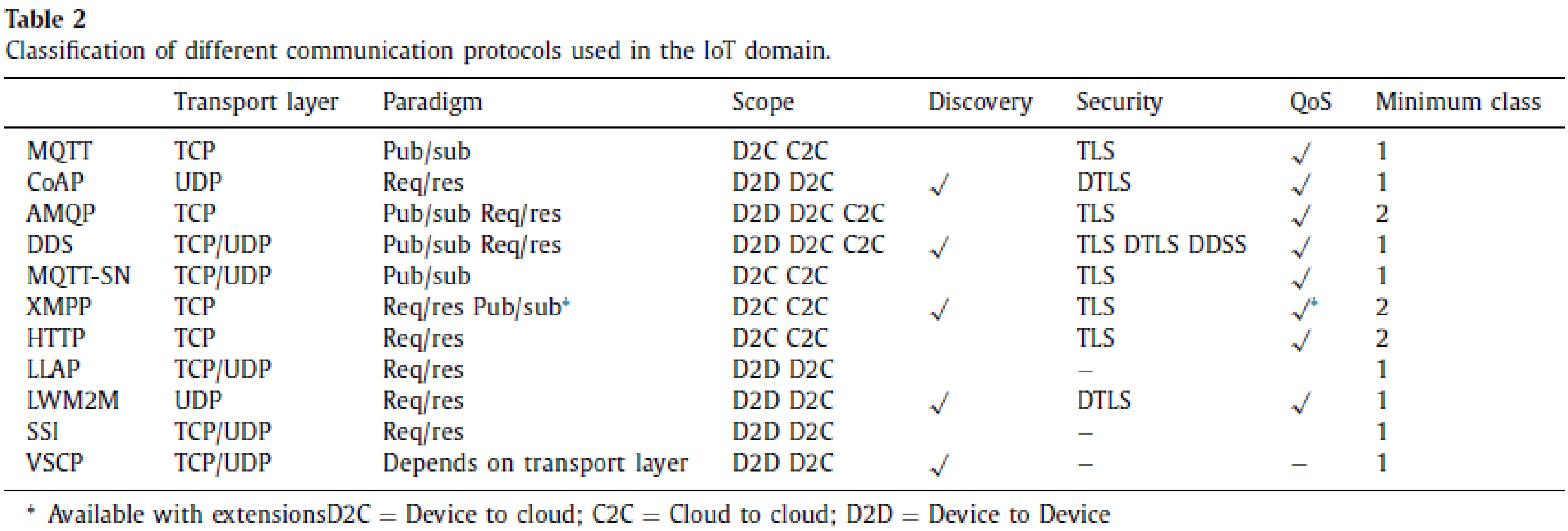

Table 2
Classification of different communication protocols used in the IoT domain.

	Transport layer	Paradigm	Scope	Discovery	Security	QoS	Minimum class
MQTT	TCP	Pub/sub	D2C C2C		TLS	✓	1
CoAP	UDP	Req/res	D2D D2C	✓	DTLS	✓	1
AMQP	TCP	Pub/sub Req/res	D2D D2C C2C		TLS	✓	2
DDS	TCP/UDP	Pub/sub Req/res	D2D D2C C2C	✓	TLS DTLS DDSS	✓	1
MQTT-SN	TCP/UDP	Pub/sub	D2C C2C		TLS	✓	1
XMPP	TCP	Req/res Pub/sub*	D2C C2C	✓	TLS	✓*	2
HTTP	TCP	Req/res	D2C C2C		TLS	✓	2
LLAP	TCP/UDP	Req/res	D2D D2C		–		1
LWM2M	UDP	Req/res	D2D D2C	✓	DTLS	✓	1
SSI	TCP/UDP	Req/res	D2D D2C		–		1
VSCP	TCP/UDP	Depends on transport layer	D2D D2C	✓	–	–	1

* Available with extensionsD2C = Device to cloud; C2C = Cloud to cloud; D2D = Device to Device

MQTT – Message Queuing Telemetry Transport
CoAP – Constrained Application Protocol
AMQP – Advanced Message Queuing Protocol
DDS – Data Distribution Service
MQTT-SM – MQTT for Sensor Network
...

- Request-Response
- Publish-Subscribe

QoS – Quality of Service

TLS: Transport Layer Security
DTLS: Datagram TLS

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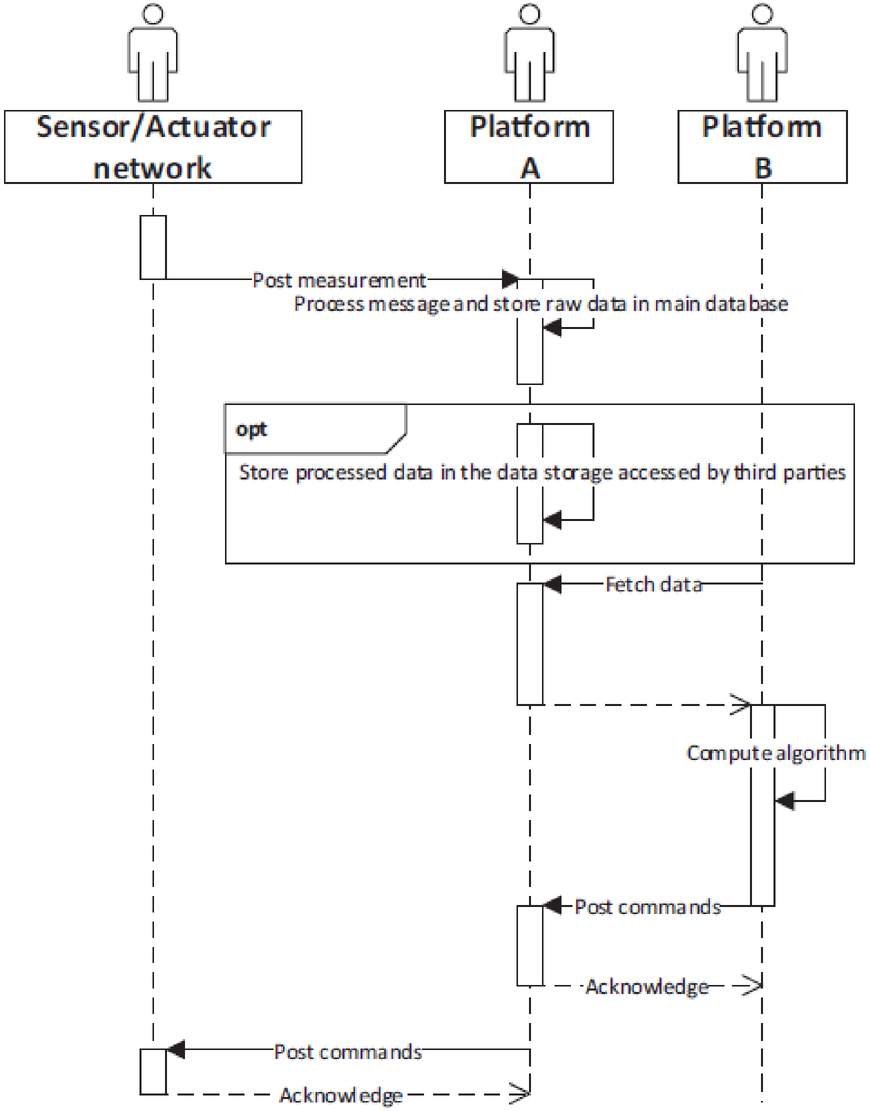


Fig. 5. Sequence diagram of the message exchange between two platforms: Platform A, owner of energy data needed by Platform B who intends to solve a contingency.

Simulators, Emulators, and Test-beds for Internet of Things: A Comparison, Patel et al. IoT in Social, Mobile, Analytics and Cloud: I-SMAC 2019

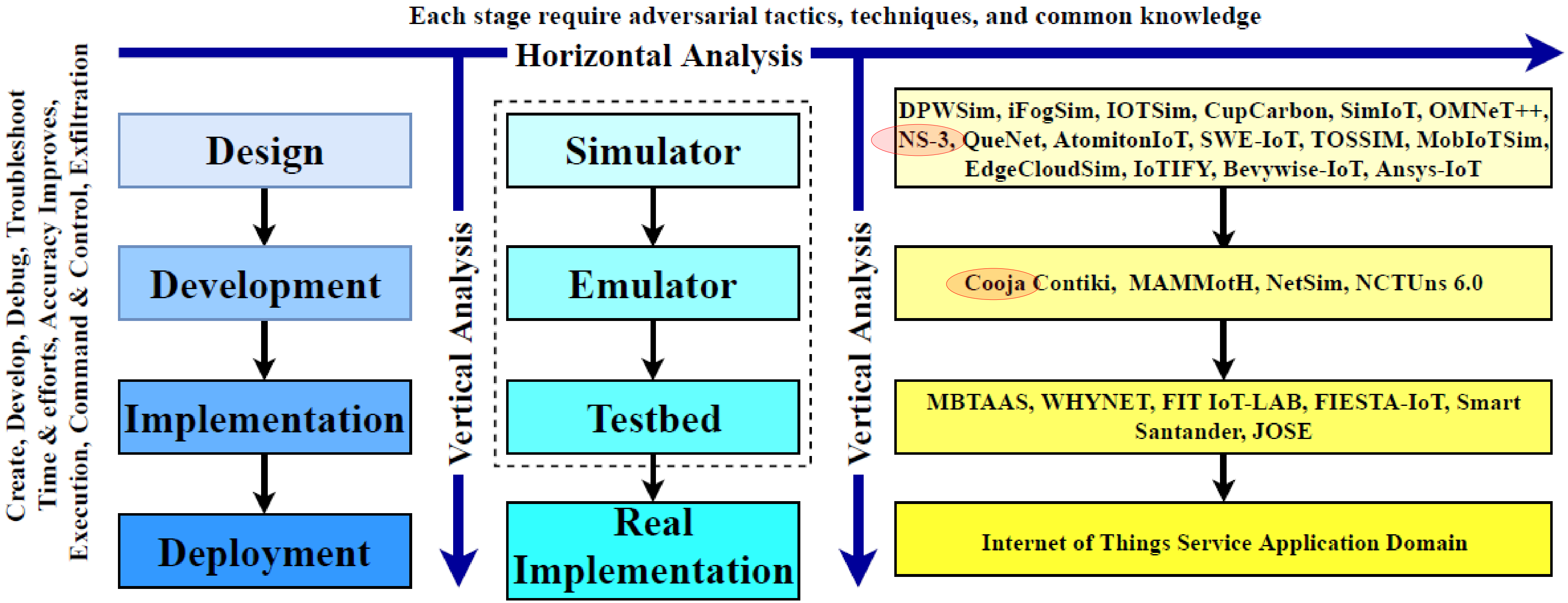
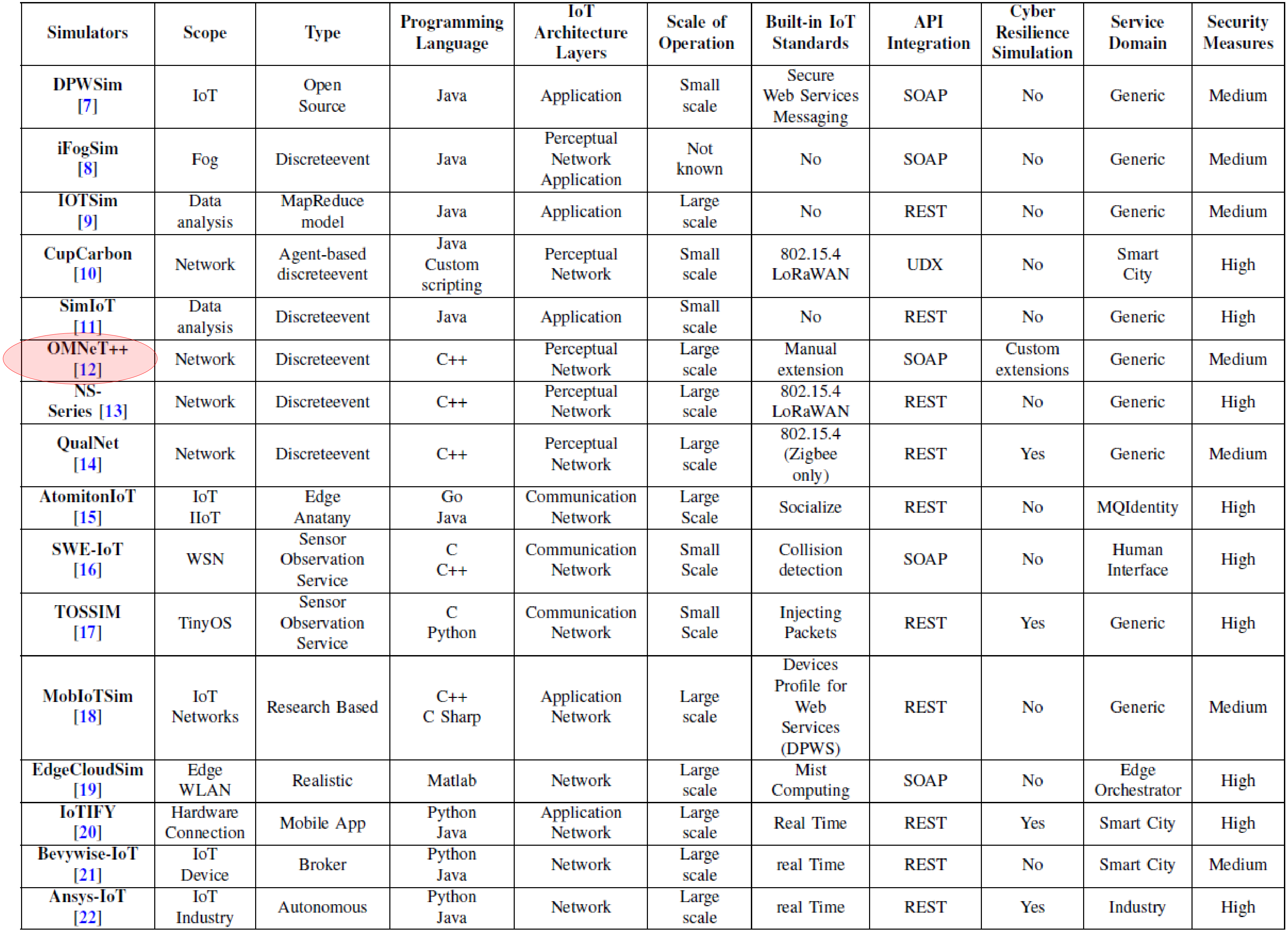


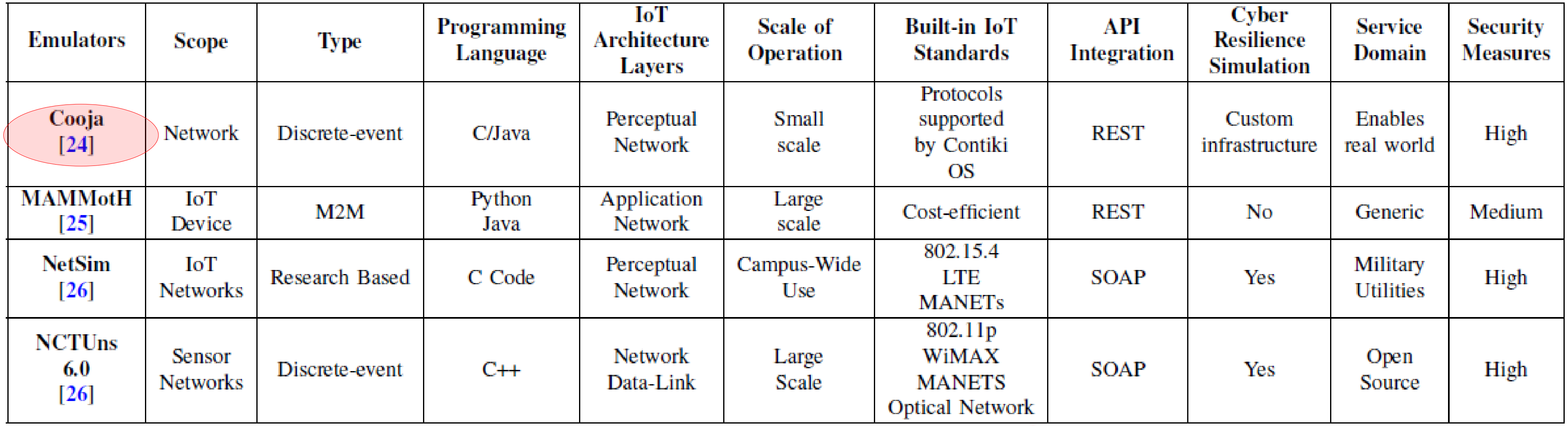
Figure 1: Summary of "Vertical Analysis" and "Horizontal Analysis" at different phases of execution evaluation



Simulators	Scope	Type	Programming Language	IoT Architecture Layers	Scale of Operation	Built-in IoT Standards	API Integration	Cyber Resilience Simulation	Service Domain	Security Measures
DPWSim [7]	IoT	Open Source	Java	Application	Small scale	Secure Web Services Messaging	SOAP	No	Generic	Medium
iFogSim [8]	Fog	Discreteevent	Java	Perceptual Network Application	Not known	No	SOAP	No	Generic	Medium
IOTSim [9]	Data analysis	MapReduce model	Java	Application	Large scale	No	REST	No	Generic	Medium
CupCarbon [10]	Network	Agent-based discreteevent	Java Custom scripting	Perceptual Network	Small scale	802.15.4 LoRaWAN	UDX	No	Smart City	High
SimIoT [11]	Data analysis	Discreteevent	Java	Application	Small scale	No	REST	No	Generic	High
OMNeT++ [12]	Network	Discreteevent	C++	Perceptual Network	Large scale	Manual extension	SOAP	Custom extensions	Generic	Medium
NS-Series [13]	Network	Discreteevent	C++	Perceptual Network	Large scale	802.15.4 LoRaWAN	REST	No	Generic	High
QualNet [14]	Network	Discreteevent	C++	Perceptual Network	Large scale	802.15.4 (Zigbee only)	REST	Yes	Generic	Medium
AtomitonIoT [15]	IoT IIoT	Edge Anatany	Go Java	Communication Network	Large Scale	Socialize	REST	No	MQIdentity	High
SWE-IoT [16]	WSN	Sensor Observation Service	C C++	Communication Network	Small Scale	Collision detection	SOAP	No	Human Interface	High
TOSSIM [17]	TinyOS	Sensor Observation Service	C Python	Communication Network	Small Scale	Injecting Packets	REST	Yes	Generic	High
MobIoTSim [18]	IoT Networks	Research Based	C++ C Sharp	Application Network	Large scale	Devices Profile for Web Services (DPWS)	REST	No	Generic	Medium
EdgeCloudSim [19]	Edge WLAN	Realistic	Matlab	Network	Large scale	Mist Computing	SOAP	No	Edge Orchestrator	High
IoTIFY [20]	Hardware Connection	Mobile App	Python Java	Application Network	Large scale	Real Time	REST	Yes	Smart City	High
Bevywise-IoT [21]	IoT Device	Broker	Python Java	Network	Large scale	real Time	REST	No	Smart City	Medium
Ansys-IoT [22]	IoT Industry	Autonomous	Python Java	Network	Large scale	real Time	REST	Yes	Industry	High

Table I: Comparison of Selected IoT Simulators

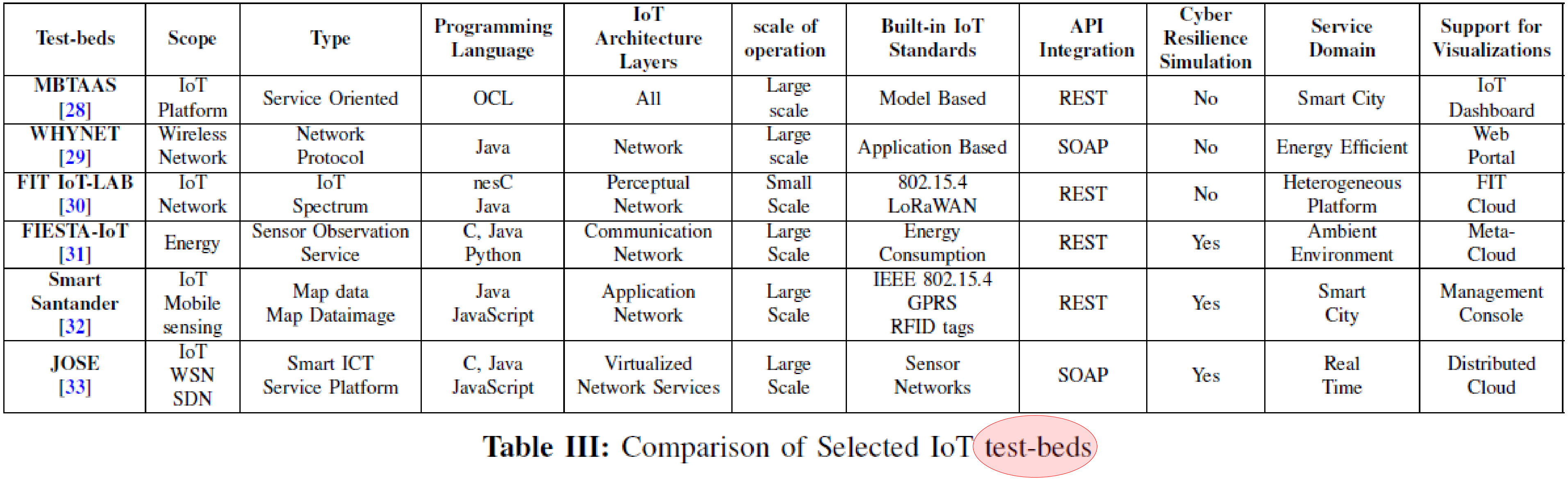
Simulators, Emulators, and Test-beds for Internet of Things: A Comparison, Patel et al. IoT in Social, Mobile, Analytics and Cloud: I-SMAC 2019



Emulators	**Scope**	**Type**	**Programming Language**	**IoT Architecture Layers**	**Scale of Operation**	**Built-in IoT Standards**	**API Integration**	**Cyber Resilience Simulation**	**Service Domain**	**Security Measures**
Cooja [24]	Network	Discrete-event	C/Java	Perceptual Network	Small scale	Protocols supported by Contiki OS	REST	Custom infrastructure	Enables real world	High
MAMMotH [25]	IoT Device	M2M	Python Java	Application Network	Large scale	Cost-efficient	REST	No	Generic	Medium
NetSim [26]	IoT Networks	Research Based	C Code	Perceptual Network	Campus-Wide Use	802.15.4 LTE MANETs	SOAP	Yes	Military Utilities	High
NCTUns 6.0 [26]	Sensor Networks	Discrete-event	C++	Network Data-Link	Large Scale	802.11p WiMAX MANETS Optical Network	SOAP	Yes	Open Source	High

Table II: Comparison of Selected IoT Emulators

Simulators, Emulators, and Test-beds for Internet of Things: A Comparison, Patel et al. IoT in Social, Mobile, Analytics and Cloud: I-SMAC 2019



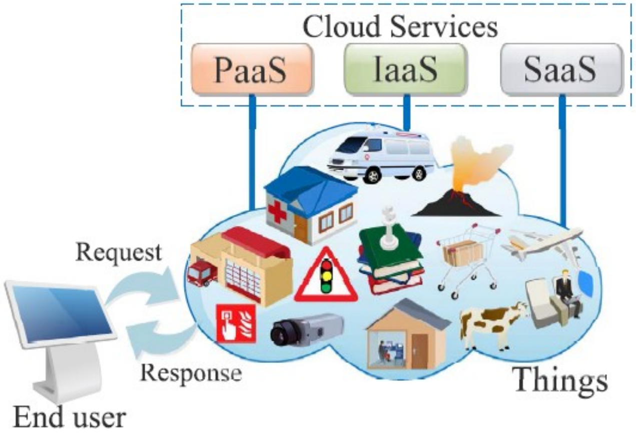
Test-beds	Scope	Type	Programming Language	IoT Architecture Layers	scale of operation	Built-in IoT Standards	API Integration	Cyber Resilience Simulation	Service Domain	Support for Visualizations
MBTAAS [28]	IoT Platform	Service Oriented	OCL	All	Large scale	Model Based	REST	No	Smart City	IoT Dashboard
WHYNET [29]	Wireless Network	Network Protocol	Java	Network	Large scale	Application Based	SOAP	No	Energy Efficient	Web Portal
FIT IoT-LAB [30]	IoT Network	IoT Spectrum	nesC Java	Perceptual Network	Small Scale	802.15.4 LoRaWAN	REST	No	Heterogeneous Platform	FIT Cloud
FIESTA-IoT [31]	Energy	Sensor Observation Service	C, Java Python	Communication Network	Large Scale	Energy Consumption	REST	Yes	Ambient Environment	Meta-Cloud
Smart Santander [32]	IoT Mobile sensing	Map data Map Dataimage	Java JavaScript	Application Network	Large Scale	IEEE 802.15.4 GPRS RFID tags	REST	Yes	Smart City	Management Console
JOSE [33]	IoT WSN SDN	Smart ICT Service Platform	C, Java JavaScript	Virtualized Network Services	Large Scale	Sensor Networks	SOAP	Yes	Real Time	Distributed Cloud

Table III: Comparison of Selected IoT test-beds

Fog/Edge Computing-Based IoT (FECIoT): Architecture, Applications, and Research Issues,

Omoniwa et al. IEEE INTERNET OF THINGS JOURNAL, VOL. 6, NO. 3, JUNE 2019

Acronym	*Definition*
3GPP	Third Generation Partnership Project
5G	Fifth Generation
6LoWPAN	IPv6 over Low Power WPAN
BLE	Bluetooth Low Energy
BSN	Body Sensor Networks
CAN	Controller Area Network
CCTV	Closed-Circuit Television
CoAP	Constrained Application Protocol
CoRE	Constrained RESTful Environments
CORPL	Cognitive Ripple Routing Protocol
CPS	Cyber-Physical Systems
DODAG	Destination Oriented Directed Acyclic Graph
DTLS	Datagram Transport Layer Security
FEC	Fog/Edge Computing
FaaS	Fog-as-a-Service
GATT	Generic Attribute Profiles
HaaS	Hardware-as-a-Service
HTTPS	Hypertext Transfer Protocol Secure
IaaS	Infrastructure-as-a-Service
IEC	International Electrotechnical Commissic
IEEE	Institute of Electrical and Electronics En
IETF	Internet Engineering Task Force
IPSec	Internet Protocol Security
IPv4/v6	Internet Protocol version 4/6
ISM	Industrial, Scientific, and Medical
ITS	Intelligent Transportation Systems
ITU	International Telecommunication Union
LTE-A	Long Term Evolution-Advanced
MANET	Mobile Ad hoc Network
MDC	Microdata Center
MEC	Mobile Edge Computing
NFC	Near Field Communication
OaaS	Offload-as-a-Service
OC	Offload Computation
OSGi	Open Service Gateway
P2P	Peer-to-Peer
PaaS	Platform-as-a-Service
PAN	Personal Area Networks
PDU	Protocol Data Unit
QoS	Quality of Service
RAN	Radio Area Network
REST	REpresentational State Transfer
RFID	Radio-Frequency Identification
ROLL	Routing Over Low power and Lossy
SaaS	Software-as-a-Service
SCADA	Supervisory Control and Data Acquisition
SoA	Service-oriented Architecture
SOAP	Simple Object Access Protocol
TCP	Transmission Control Protocol
TEDS	Transducer Electronic Data Sheets
UDP	User Datagram Protocol
W3C	World Wide Web Consortium
WISP	Wireless Identification and Sensing Platform
WLAN	Wireless Local Area Networks
WPAN	Wireless Personal Area Networks
WSDL	Web Service Description Language
WSN	Wireless Sensor Network
XML	Extensible Markup Language



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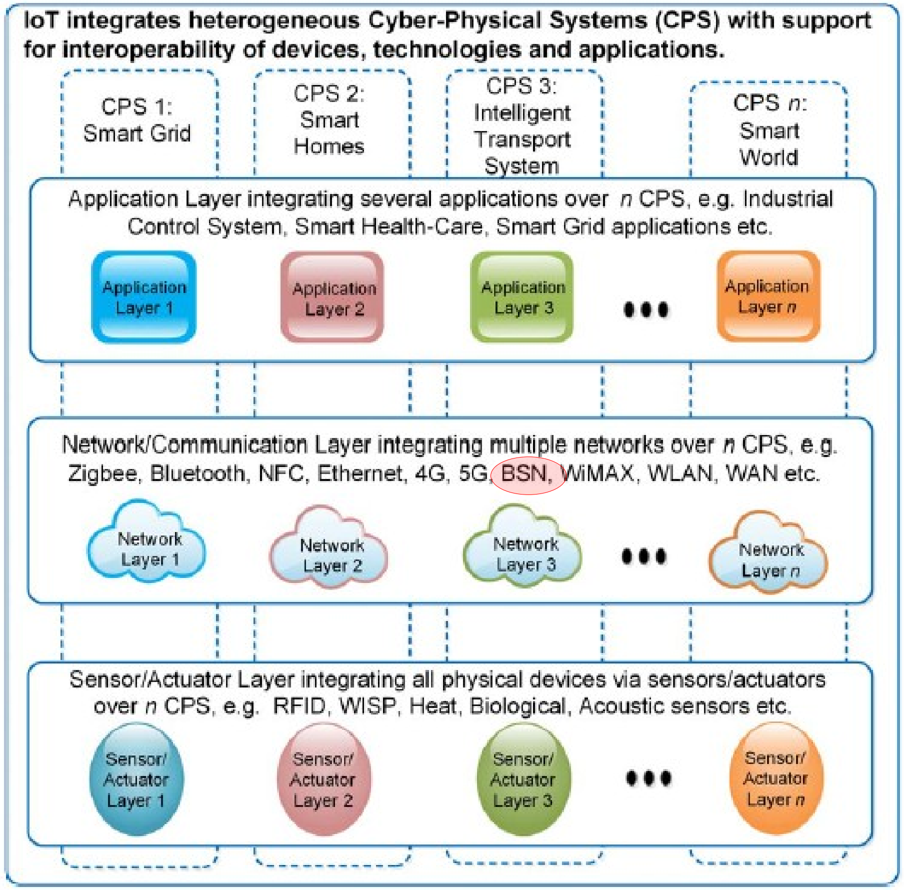

*Blockchain-based Service Network

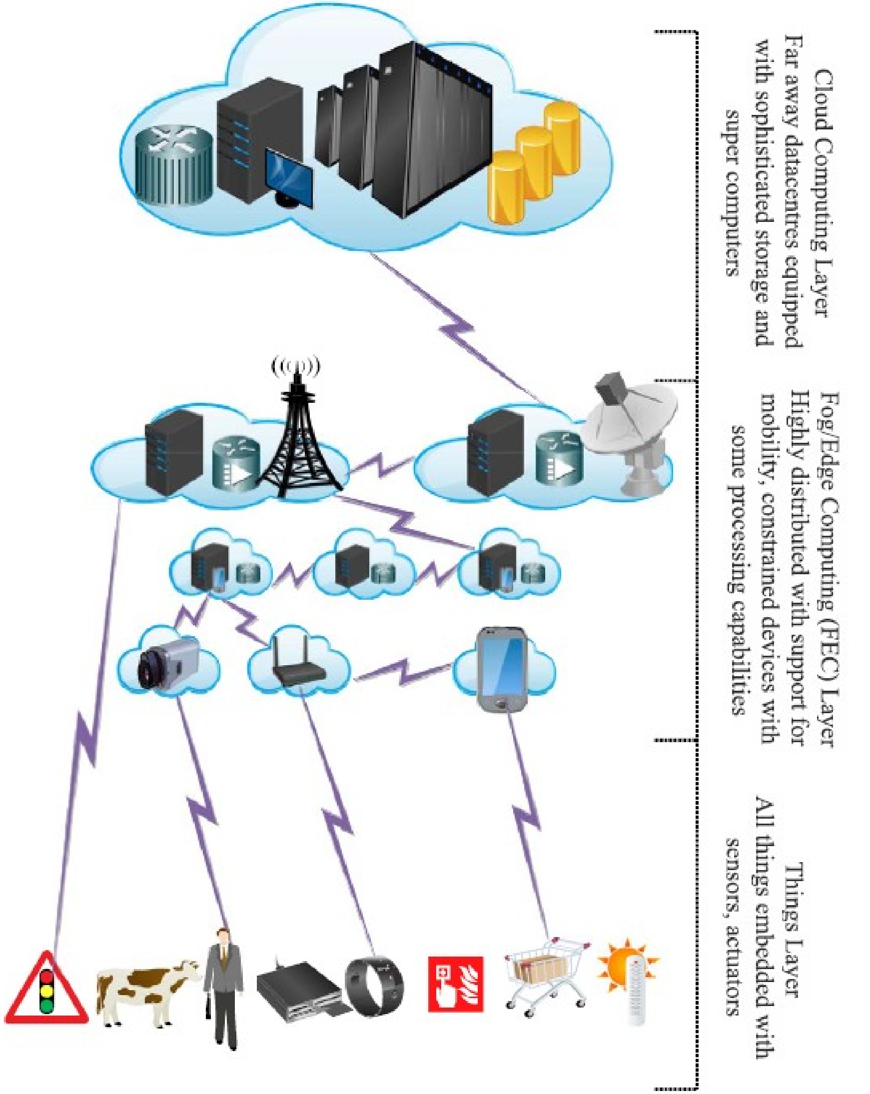

Fig. 2. FEC architecture and interaction in the Cloud-to-Things continuum.

Fog/Edge Computing-Based IoT (FECIoT): Architecture, Applications, and Research Issues,

Omoniwa et al. IEEE INTERNET OF THINGS JOURNAL, VOL. 6, NO. 3, JUNE 2019

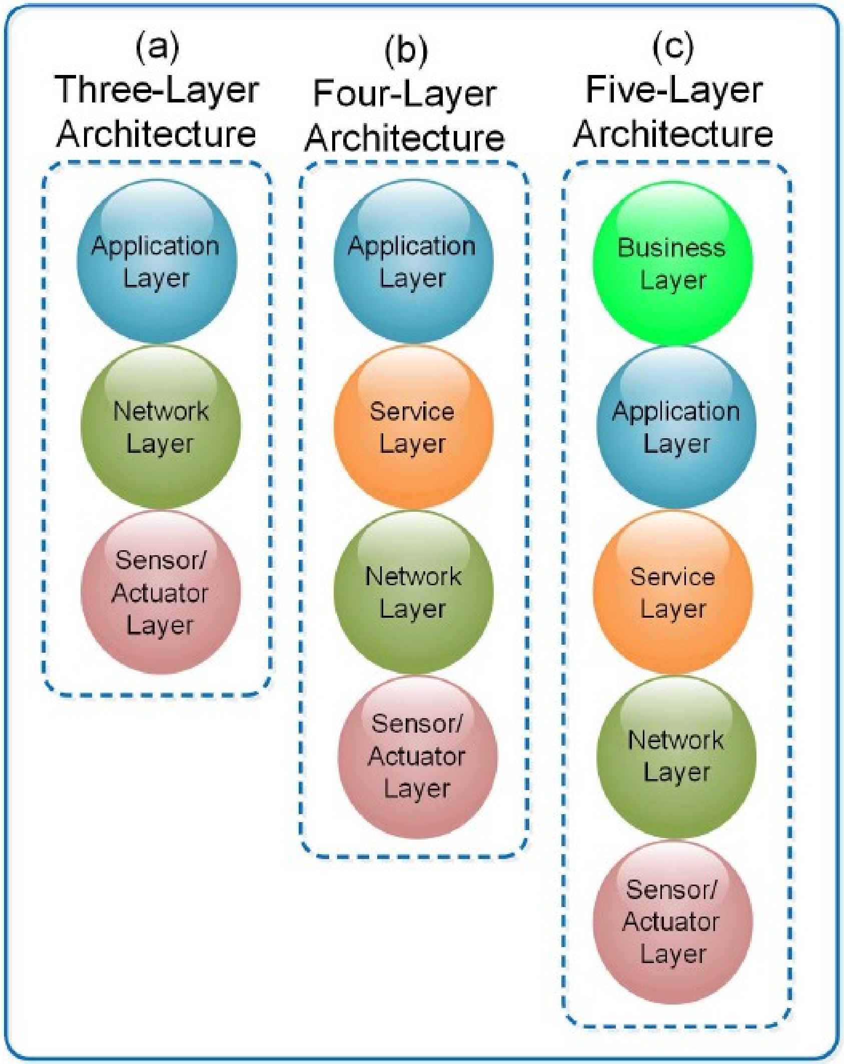

Fig. 4. FECIoT. (a) Three-layer architecture. (b) Four-layer architecture. (c) Five-layer architecture.

Fog/Edge Computing-Based IoT (FECIoT): Architecture, Applications, and Research Issues

Omoniwa et al. IEEE IoT JOURNAL, VOL. 6, NO. 3, JUNE 2019

Offload as a Service

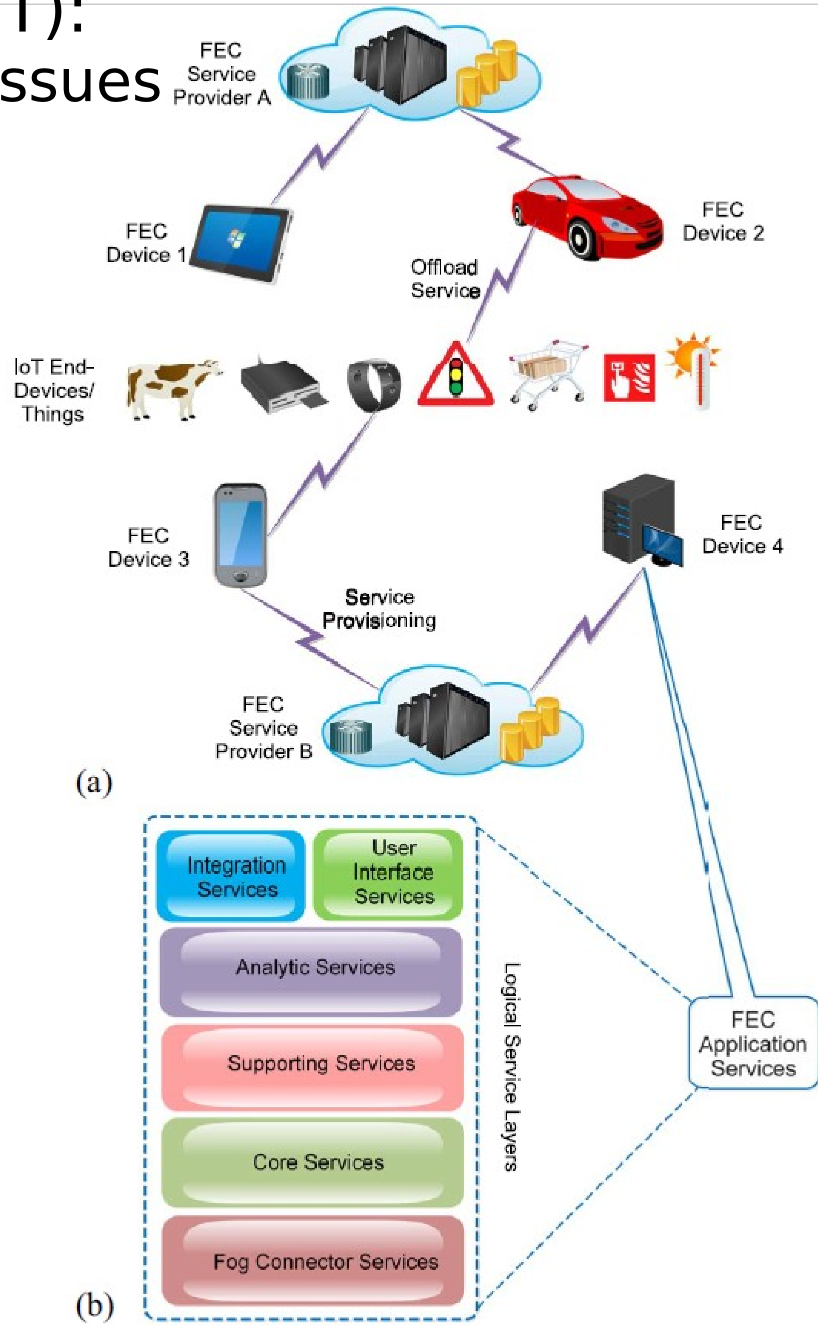

Fig 5. (a) OaaS using the FEC architecture.
(b) FEC application services.

Fog/Edge Computing-Based IoT (FECIoT): Architecture, Applications, and Research Issues,

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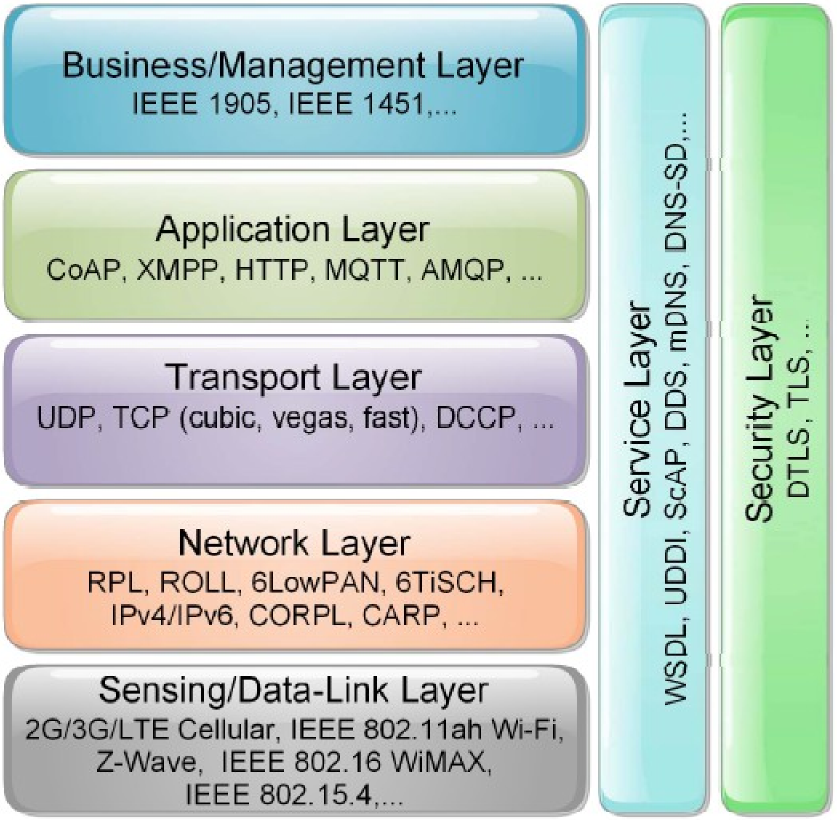

Fig. 6. Protocols within the FECIoT domain.

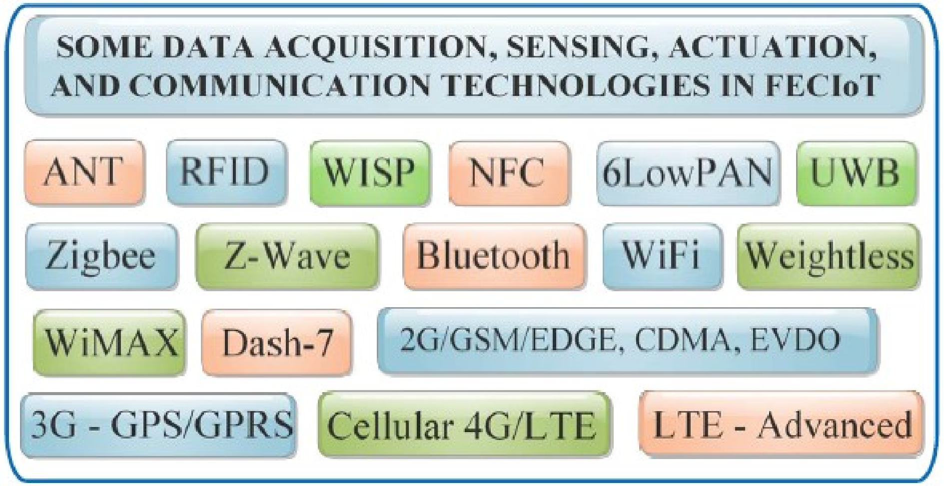

Fig. 7. Stack of some enabling technologies in FECIoT.

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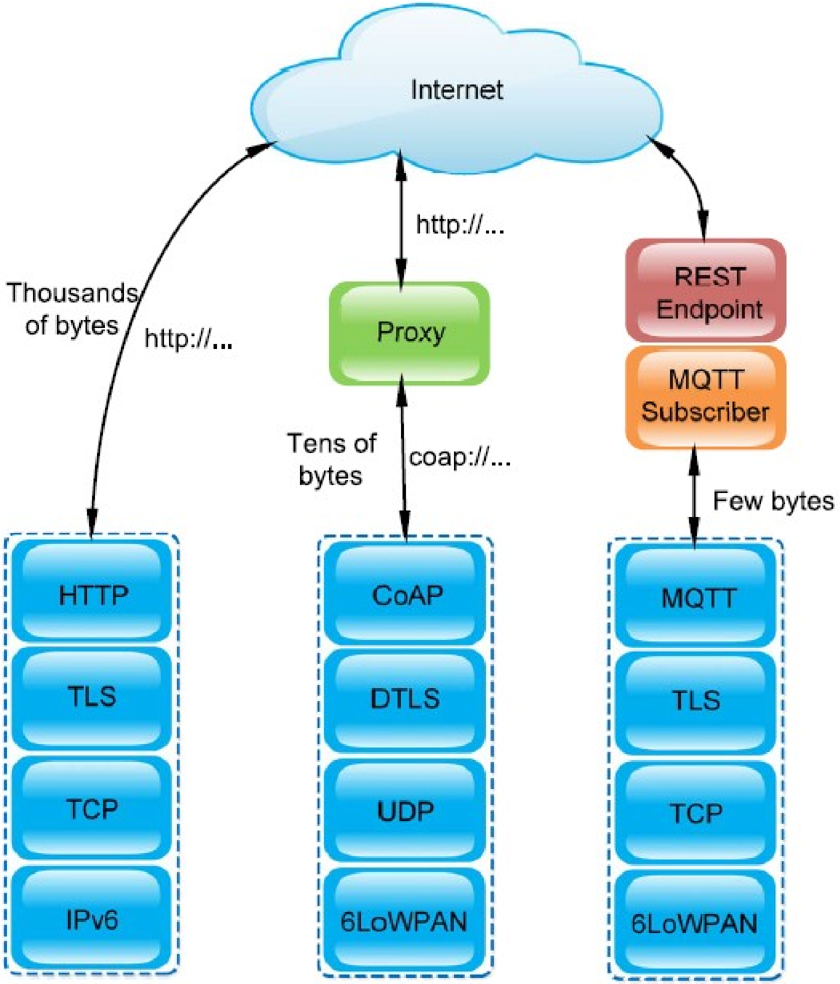

Fig. 8. Comparison of IoT protocols.

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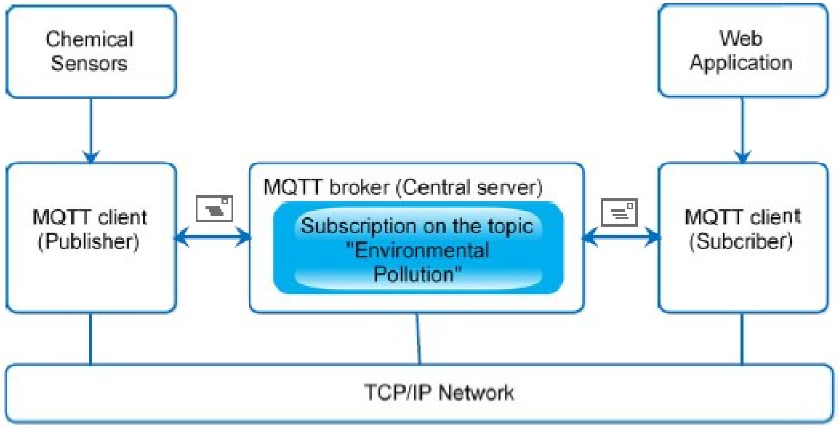

Fig. 9. MQTT architecture.

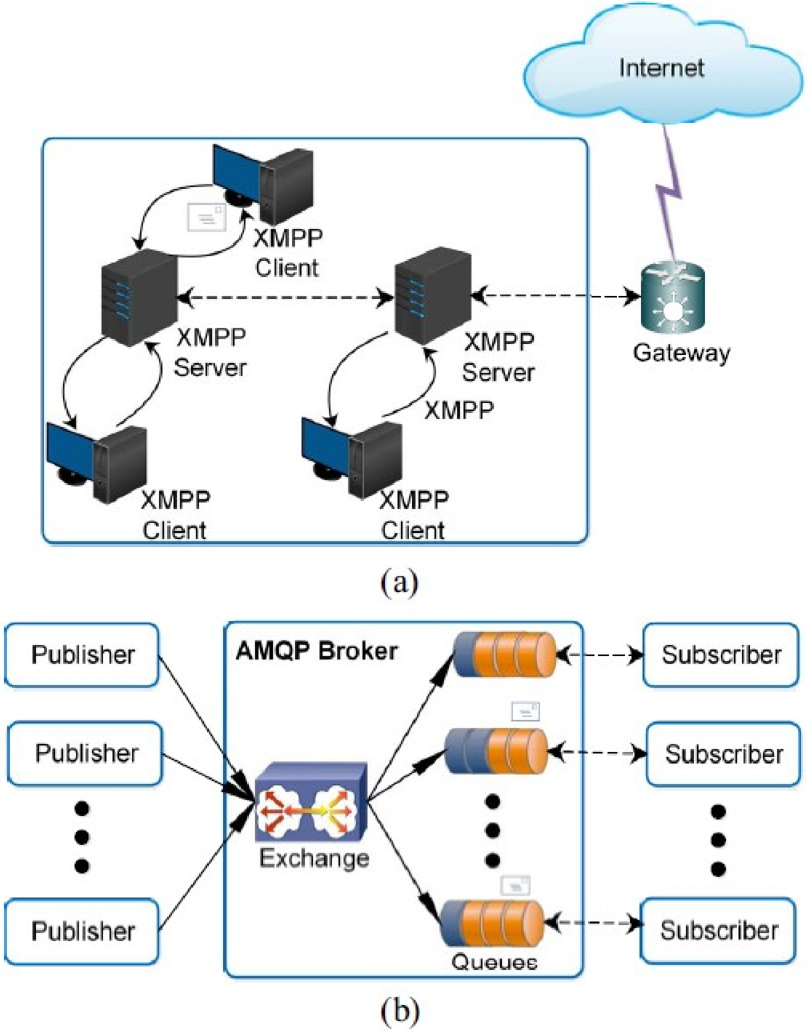

Fig. 10. Architectural model for (a) XMPP and (b) AMQP.

MQTT – Message Queuing Telemetry Transport

XMPP – Extensible Messaging and Presence Protrocol
AMQP – Advanced Message Queuing Protocol

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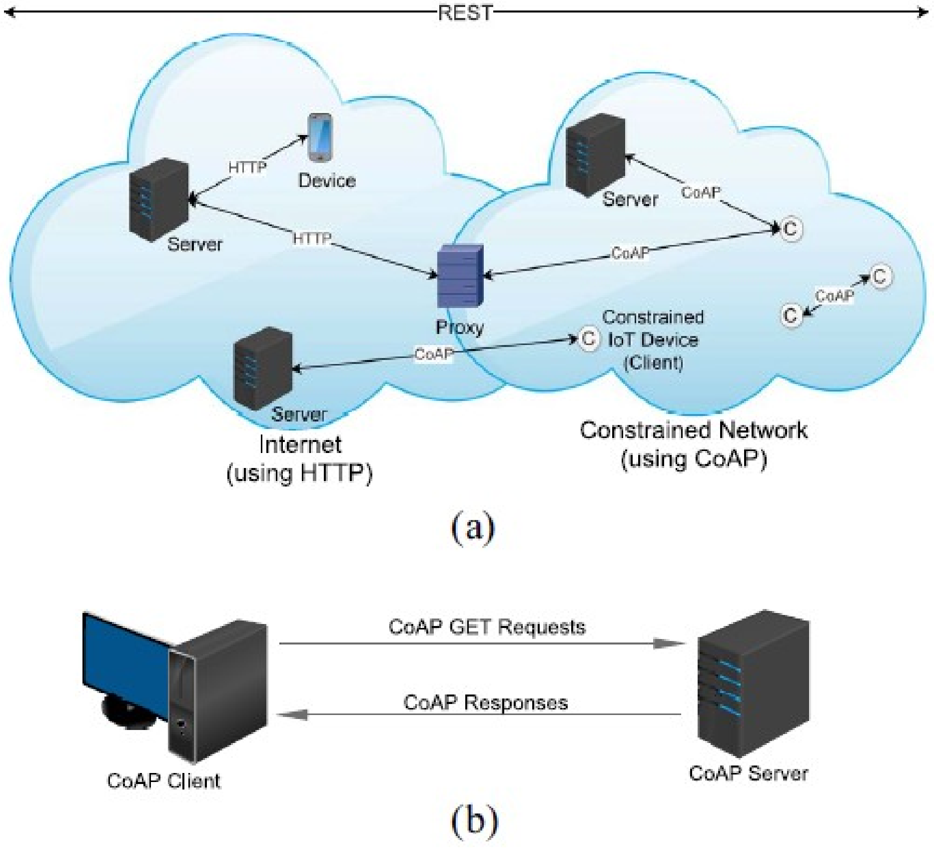

Fig. 11. (a) CoAP and HTTP in constrained and unconstrained environments. (b) CoAP interaction.

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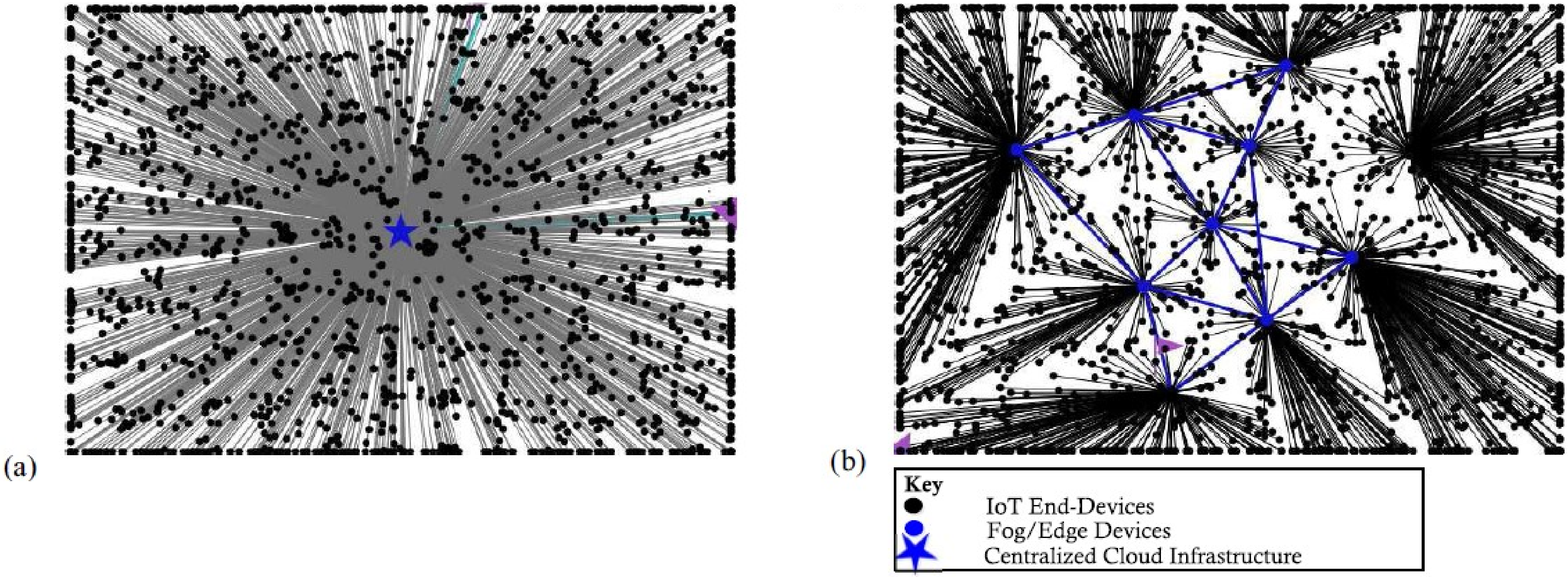

Fig. 12. NetLogo simulation using 999 IoT end-devices. (a) Centralized Cloud-to-Things model. (b) Distributed FECIoT model using ten fog nodes.

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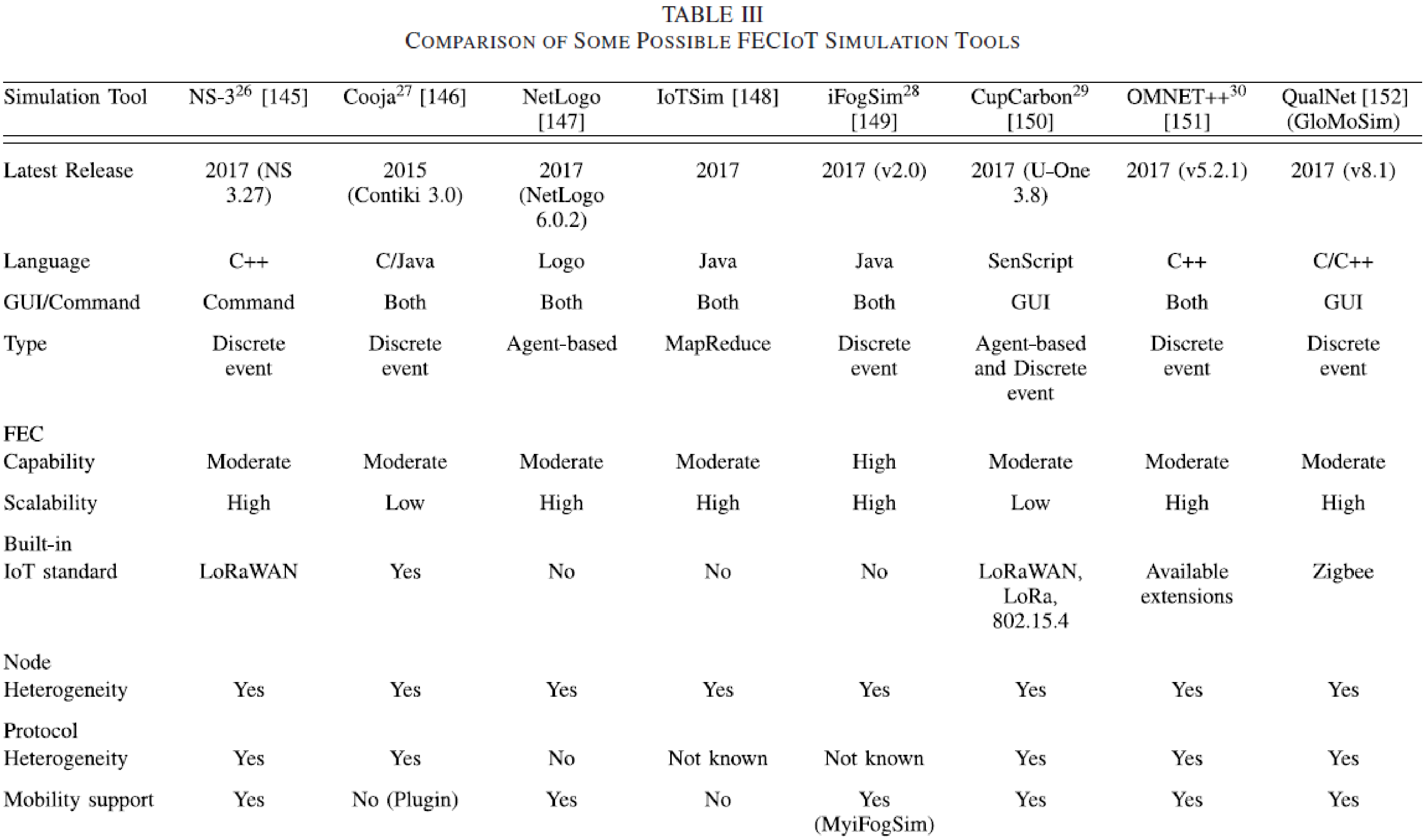

TABLE III

COMPARISON OF SOME POSSIBLE FECIOT SIMULATION TOOLS

Simulation Tool	NS-3[26] [145]	Cooja[27] [146]	NetLogo [147]	IoTSim [148]	iFogSim[28] [149]	CupCarbon[29] [150]	OMNET++[30] [151]	QualNet [152] (GloMoSim)
Latest Release	2017 (NS 3.27)	2015 (Contiki 3.0)	2017 (NetLogo 6.0.2)	2017	2017 (v2.0)	2017 (U-One 3.8)	2017 (v5.2.1)	2017 (v8.1)
Language	C++	C/Java	Logo	Java	Java	SenScript	C++	C/C++
GUI/Command	Command	Both	Both	Both	Both	GUI	Both	GUI
Type	Discrete event	Discrete event	Agent-based	MapReduce	Discrete event	Agent-based and Discrete event	Discrete event	Discrete event
FEC Capability	Moderate	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate
Scalability	High	Low	High	High	High	Low	High	High
Built-in IoT standard	LoRaWAN	Yes	No	No	No	LoRaWAN, LoRa, 802.15.4	Available extensions	Zigbee
Node Heterogeneity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Protocol Heterogeneity	Yes	Yes	No	Not known	Not known	Yes	Yes	Yes
Mobility support	Yes	No (Plugin)	Yes	No	Yes (MyiFogSim)	Yes	Yes	Yes

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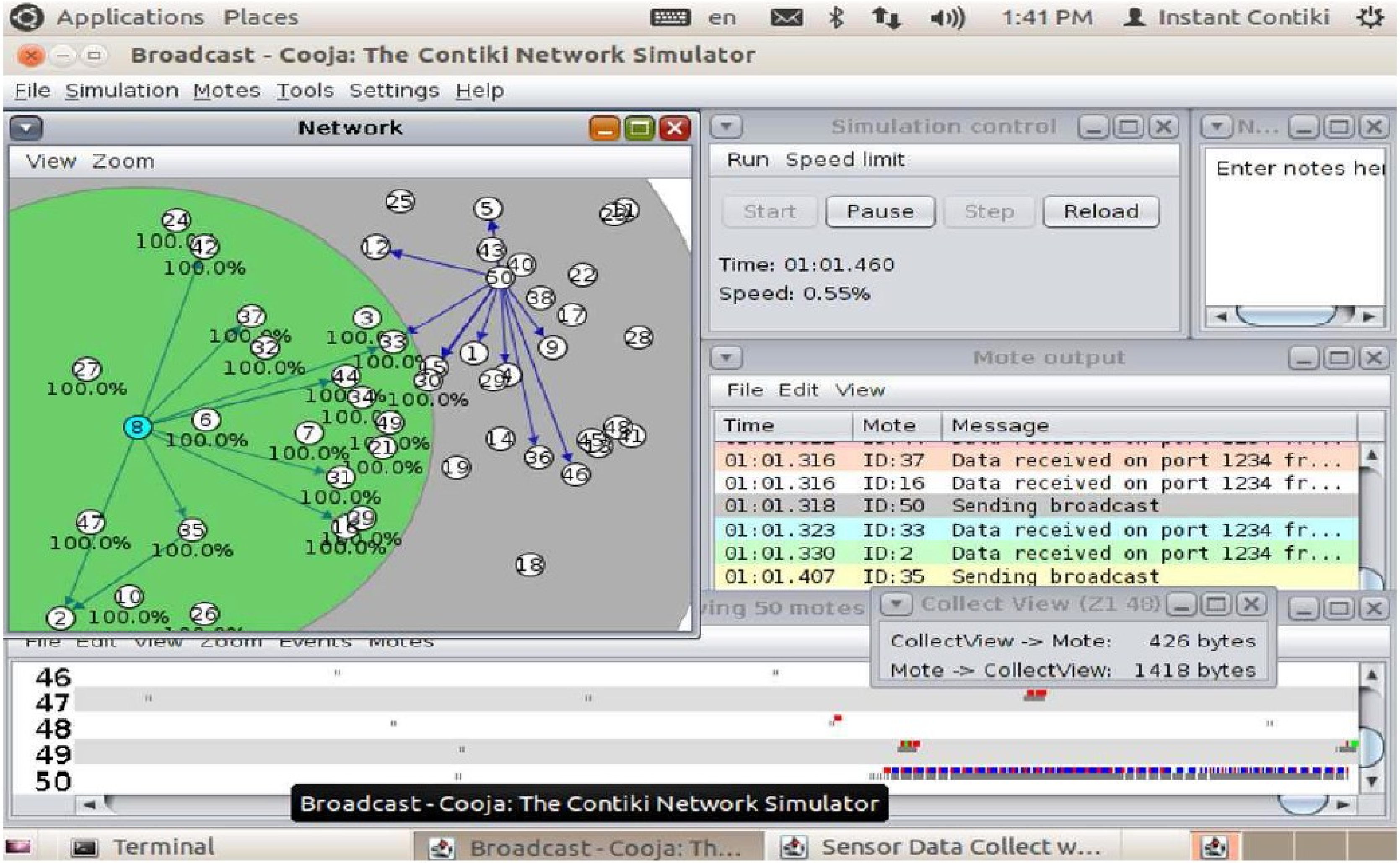

Time: 01:01.460

Speed: 0.55%

Enter notes her

Time	Mote	Message
01:01.316	ID:37	Data received on port 1234 fr...
01:01.316	ID:16	Data received on port 1234 fr...
01:01.318	ID:50	Sending broadcast
01:01.323	ID:33	Data received on port 1234 fr...
01:01.330	ID:2	Data received on port 1234 fr...
01:01.407	ID:35	Sending broadcast

CollectView -> Mote: 426 bytes

Mote -> CollectView: 1418 bytes

Fig. 14. Cooja simulation environment.

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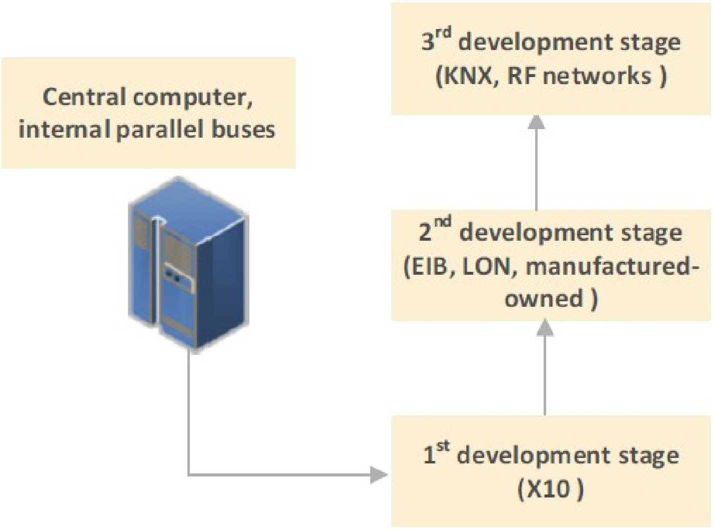
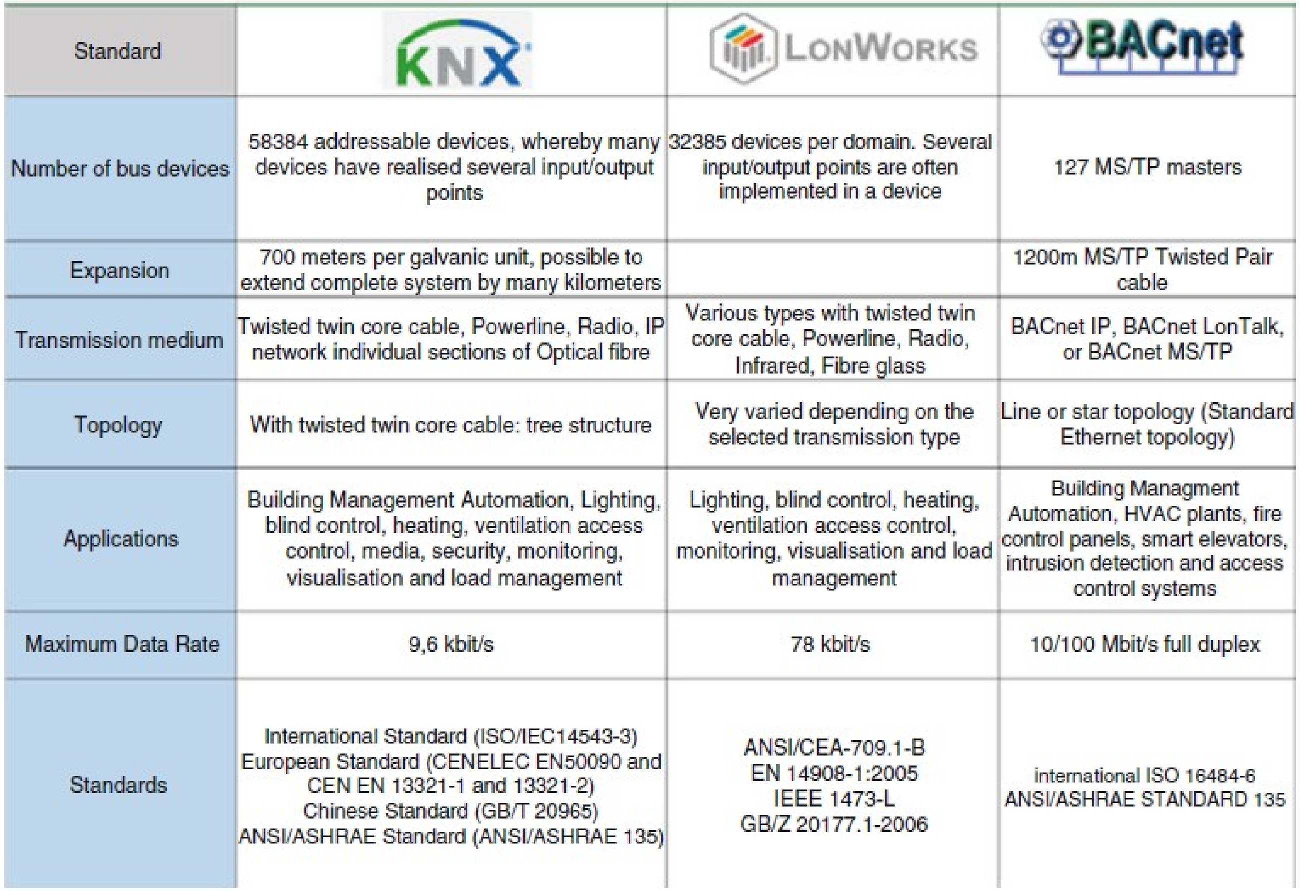


Fig. 18.1 Bus systems development stages

Table 18.1 Features of wired protocols employed in BAS



Standard	KNX	LonWorks	BACnet
Number of bus devices	58384 addressable devices, whereby many devices have realised several input/output points	32385 devices per domain. Several input/output points are often implemented in a device	127 MS/TP masters
Expansion	700 meters per galvanic unit, possible to extend complete system by many kilometers		1200m MS/TP Twisted Pair cable
Transmission medium	Twisted twin core cable, Powerline, Radio, IP network individual sections of Optical fibre	Various types with twisted twin core cable, Powerline, Radio, Infrared, Fibre glass	BACnet IP, BACnet LonTalk, or BACnet MS/TP
Topology	With twisted twin core cable: tree structure	Very varied depending on the selected transmission type	Line or star topology (Standard Ethernet topology)
Applications	Building Management Automation, Lighting, blind control, heating, ventilation access control, media, security, monitoring, visualisation and load management	Lighting, blind control, heating, ventilation access control, monitoring, visualisation and load management	Building Managment Automation, HVAC plants, fire control panels, smart elevators, intrusion detection and access control systems
Maximum Data Rate	9,6 kbit/s	78 kbit/s	10/100 Mbit/s full duplex
Standards	International Standard (ISO/IEC14543-3) European Standard (CENELEC EN50090 and CEN EN 13321-1 and 13321-2) Chinese Standard (GB/T 20965) ANSI/ASHRAE Standard (ANSI/ASHRAE 135)	ANSI/CEA-709.1-B EN 14908-1:2005 IEEE 1473-L GB/Z 20177.1-2006	international ISO 16484-6 ANSI/ASHRAE STANDARD 135

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Table 18.2 Features of wireless protocols employed in BAS

Standard	ZWAVE	ZigBee	Green. Smart. Wireless. enocean	Bluetooth	Wi Fi	THREAD
Network Topology	Mesh	Star, Tree, Mesh	Mesh	Star/Point-toPoint	Star, Mesh	Star, Mesh
Power Usage	Low	Low	Low	Low		Low
PHY/MAC Standard	ITU-T G.9959	IEEE 802.15.4	IEEE 802.15.4	IEEE 802.15.1	IEEE 802.11	IEEE 802.15.4
ISM Radio bands	868.42 MHz (Europe) 908.42 MHz (United States)	2408 to 2480 MHz	868 MHz (Europe) 902 MHz(United States)	2.4 to 2.485 GHz	2.4 GHz	2.4 GHz
Number of bus devices	up to 232	up to 64000		7 devices in one piconet region		up to 250
RF range (indoor - line of sight)	30 - 100m	70 - 400m	30 - 300m	30 - 100m	200m	30m
Maximum Data Rate	9,6 - 100 kbit/s	20 - 250 kbit/s	125 kbit/s	1 - 24 Mbit/s	250 Mbit/s	250 kbit/s
Manufacturers	up to 330	up to 76	up to 100			
Applications	Home Automation	Home Automation, Building Management Automation	Home Automation, Building Management Automation			Home Automation
Power Efficiency	√	√	√	√	x	√
Certified products	up to 1400	up to 939	up to 1200		up to 25000	up to 30

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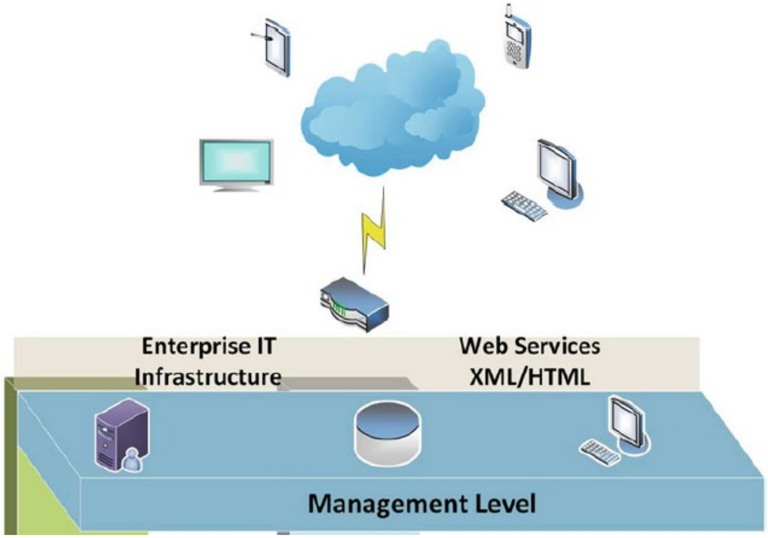
Fig. 18.2 Three-level hierarchical model of automation and control system



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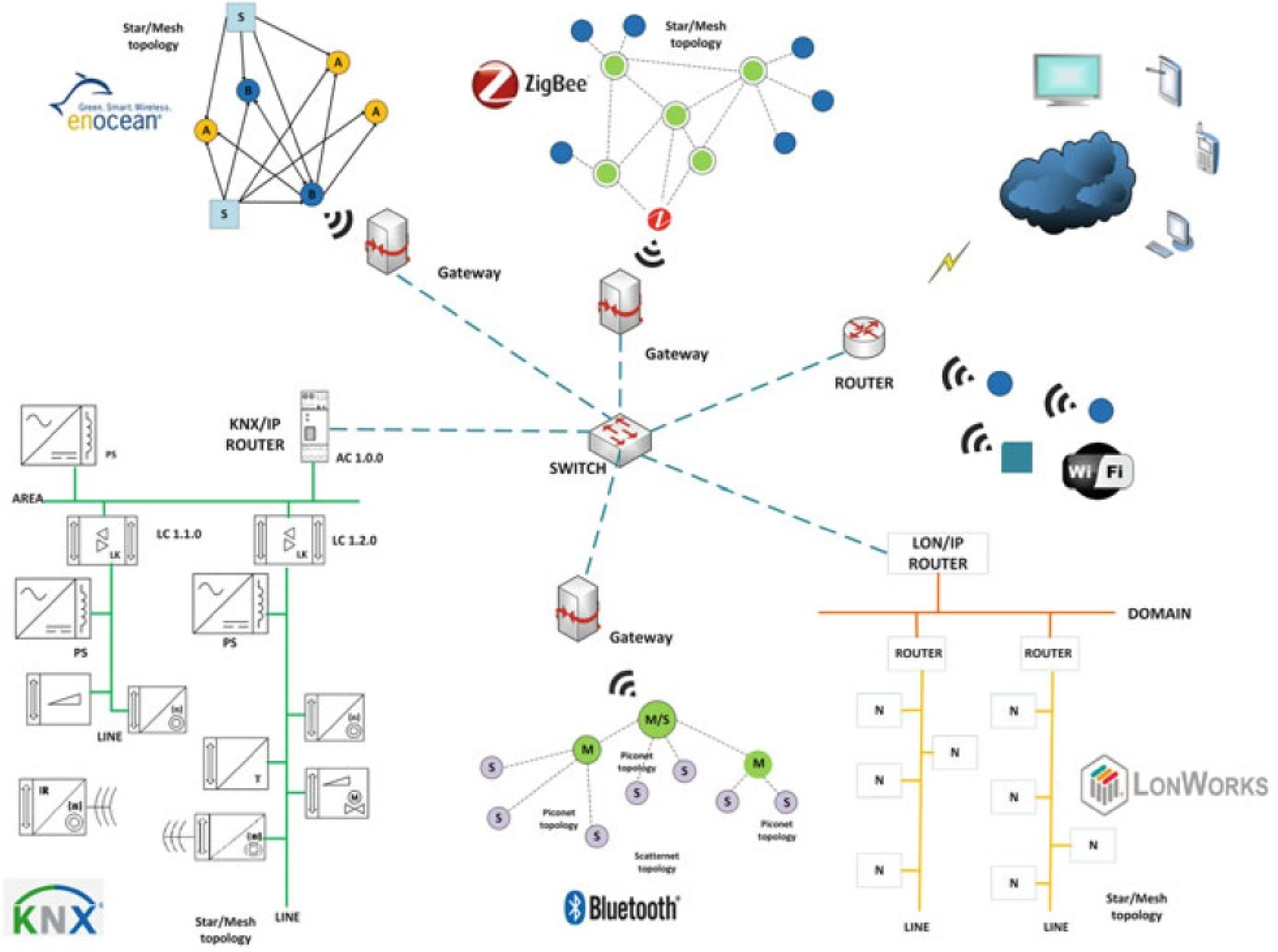

Fig. 18.3 A typical topology allowing BAS to participate in Internet of Things

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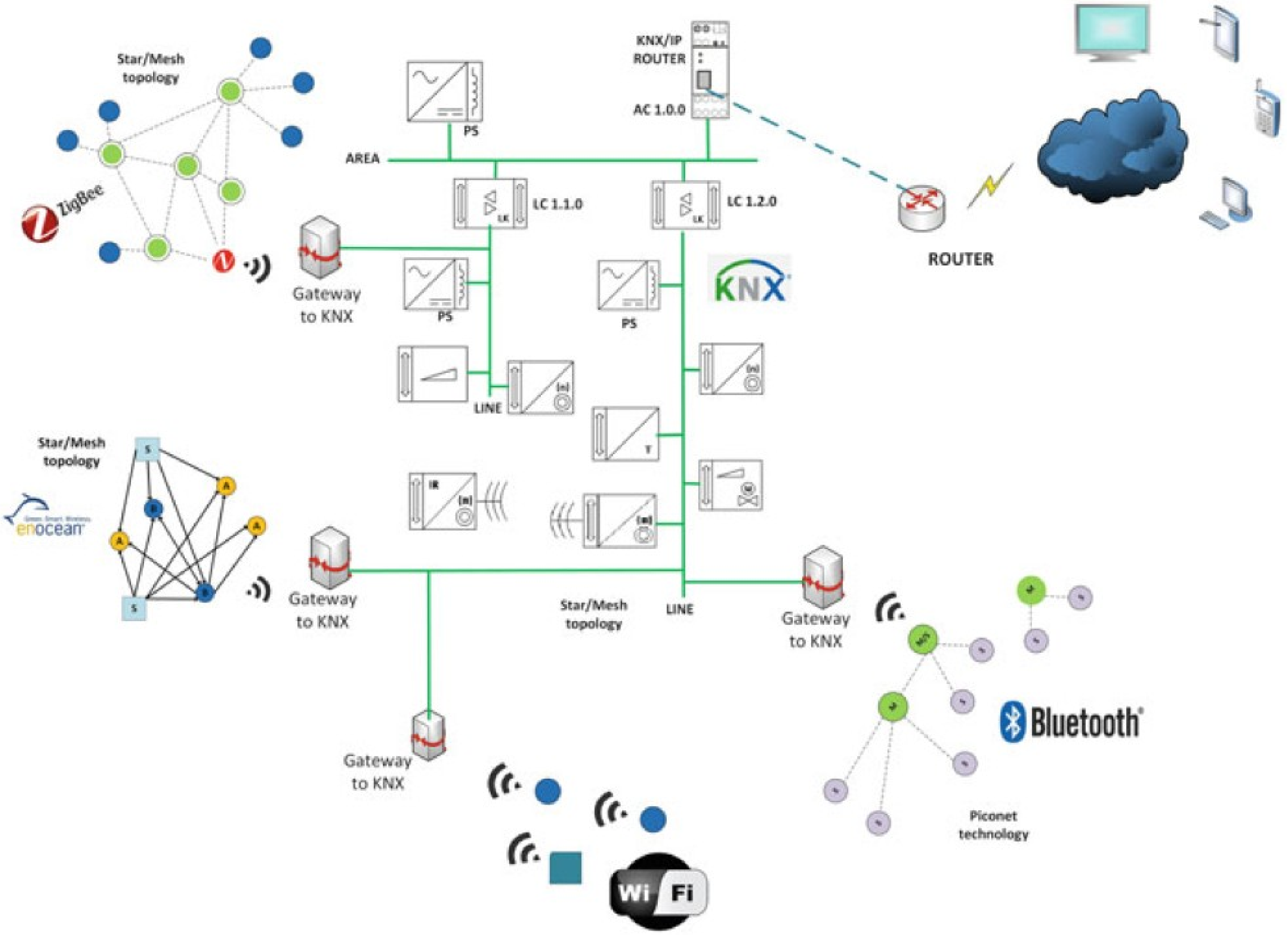

Fig. 18.4 Topology for KNX of Things

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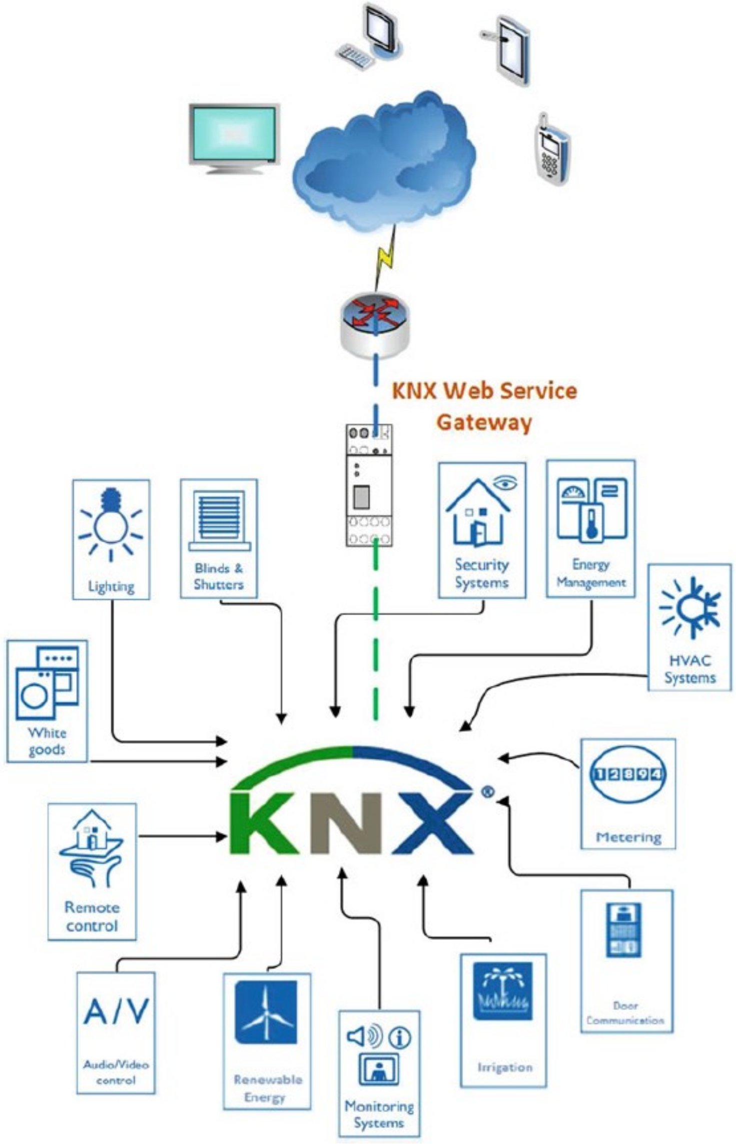

Fig. 18.5 KNX Web Services

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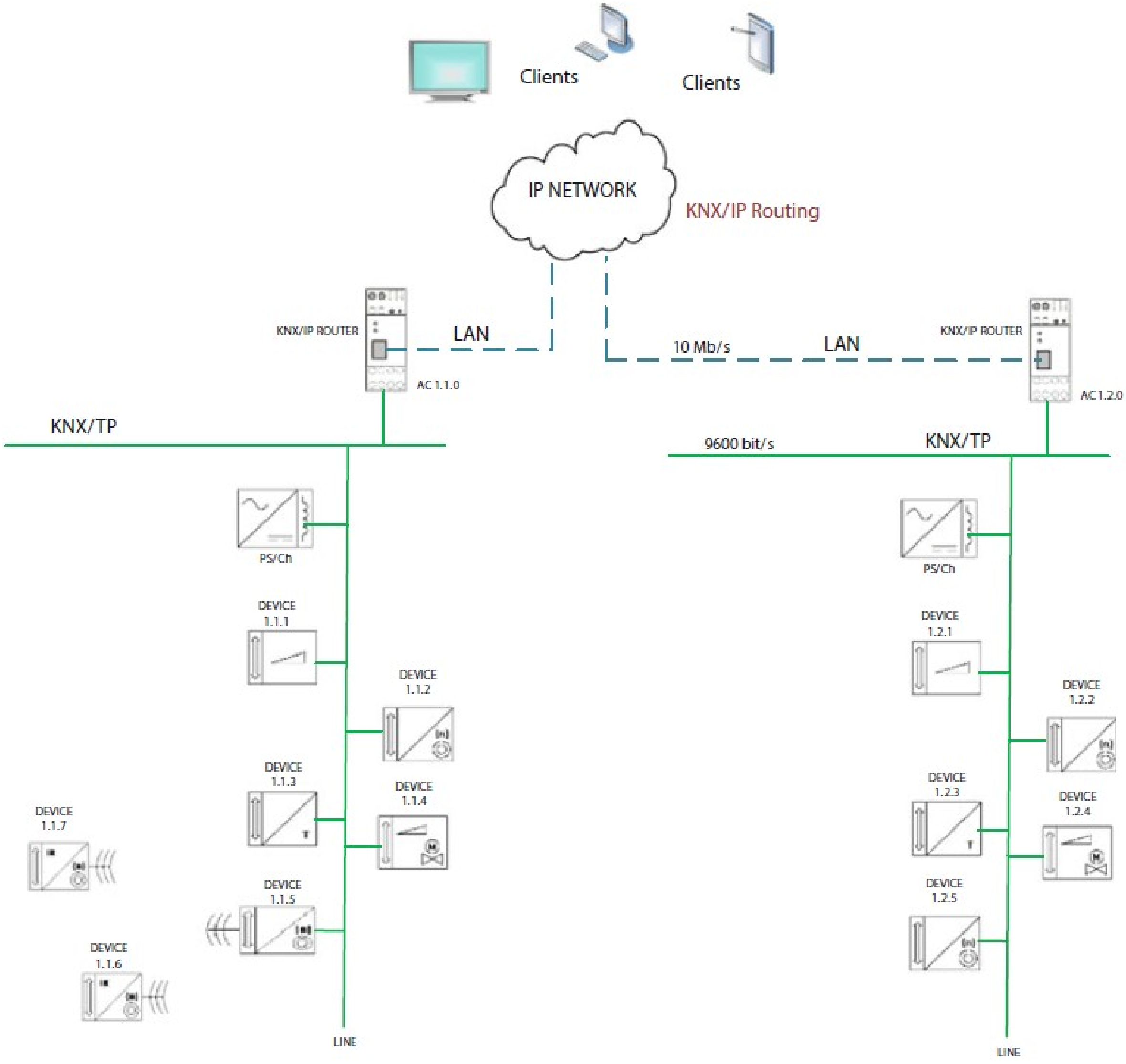

Fig. 18.7 KNX/IP Routing

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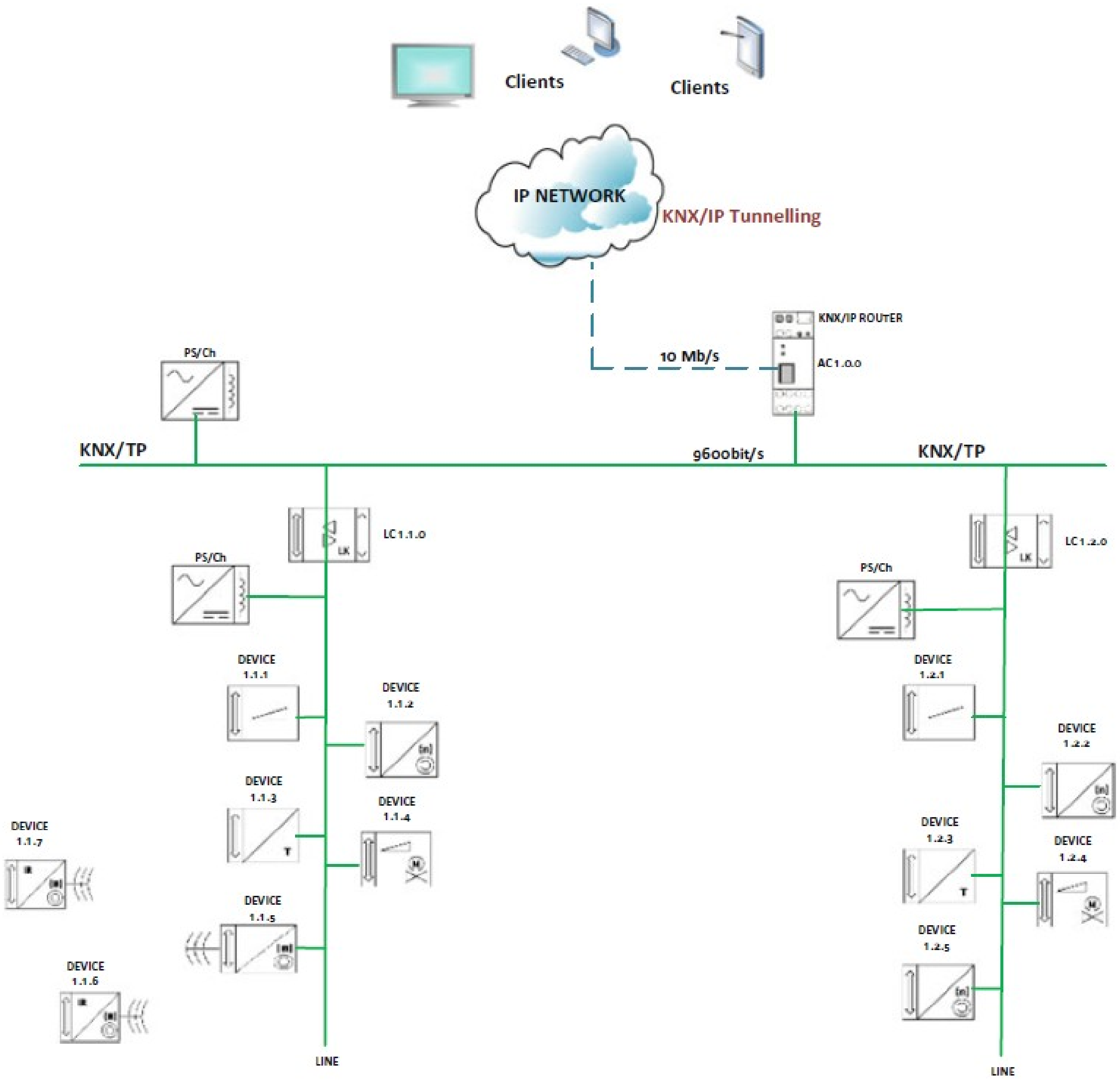

Fig. 18.8 KNX/IP Tunneling

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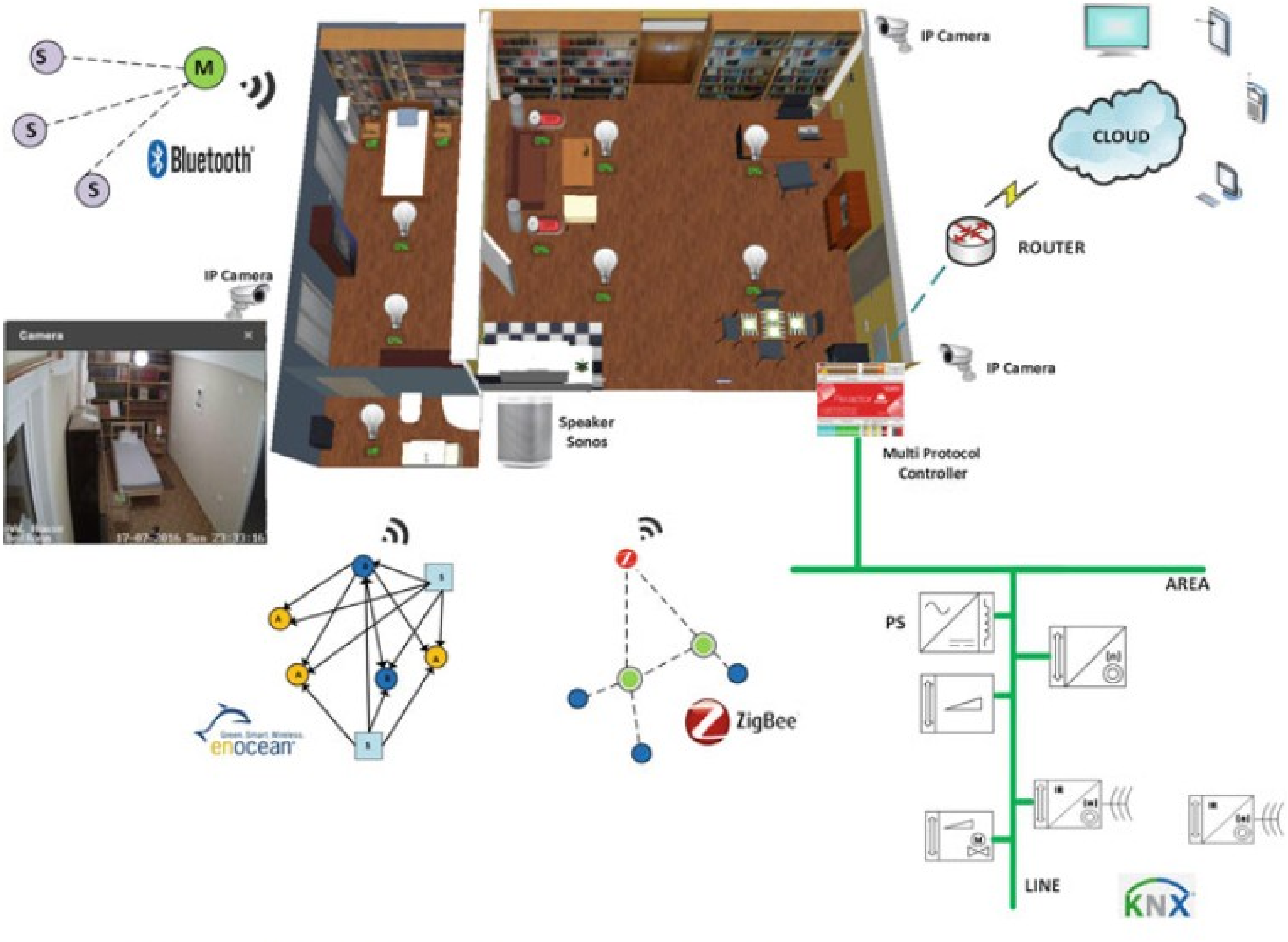

Fig. 18.9 Internet/KNX of Things infrastructure of AAL House

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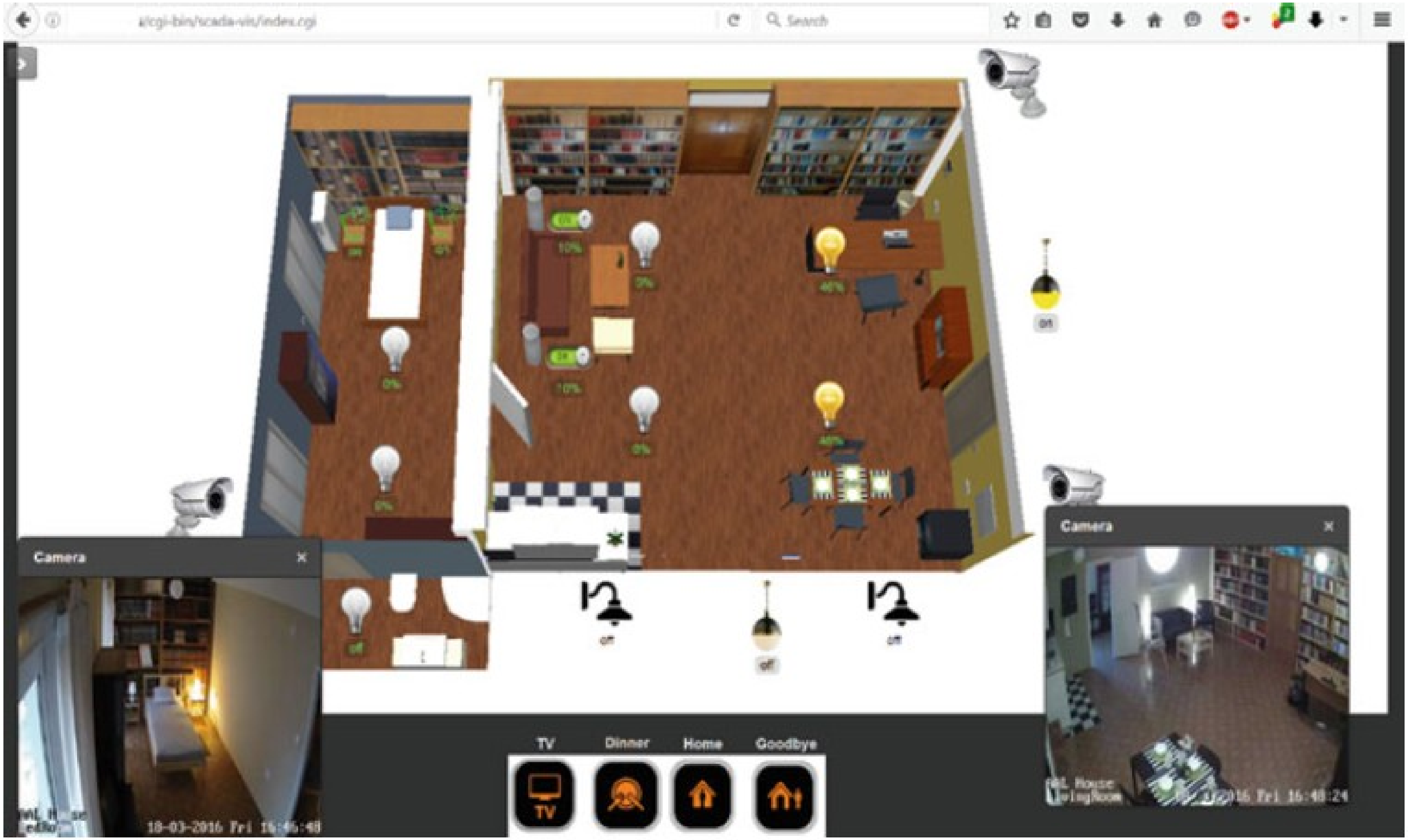

Fig. 18.10 AAL House project

Ambient Assisted Living Residence

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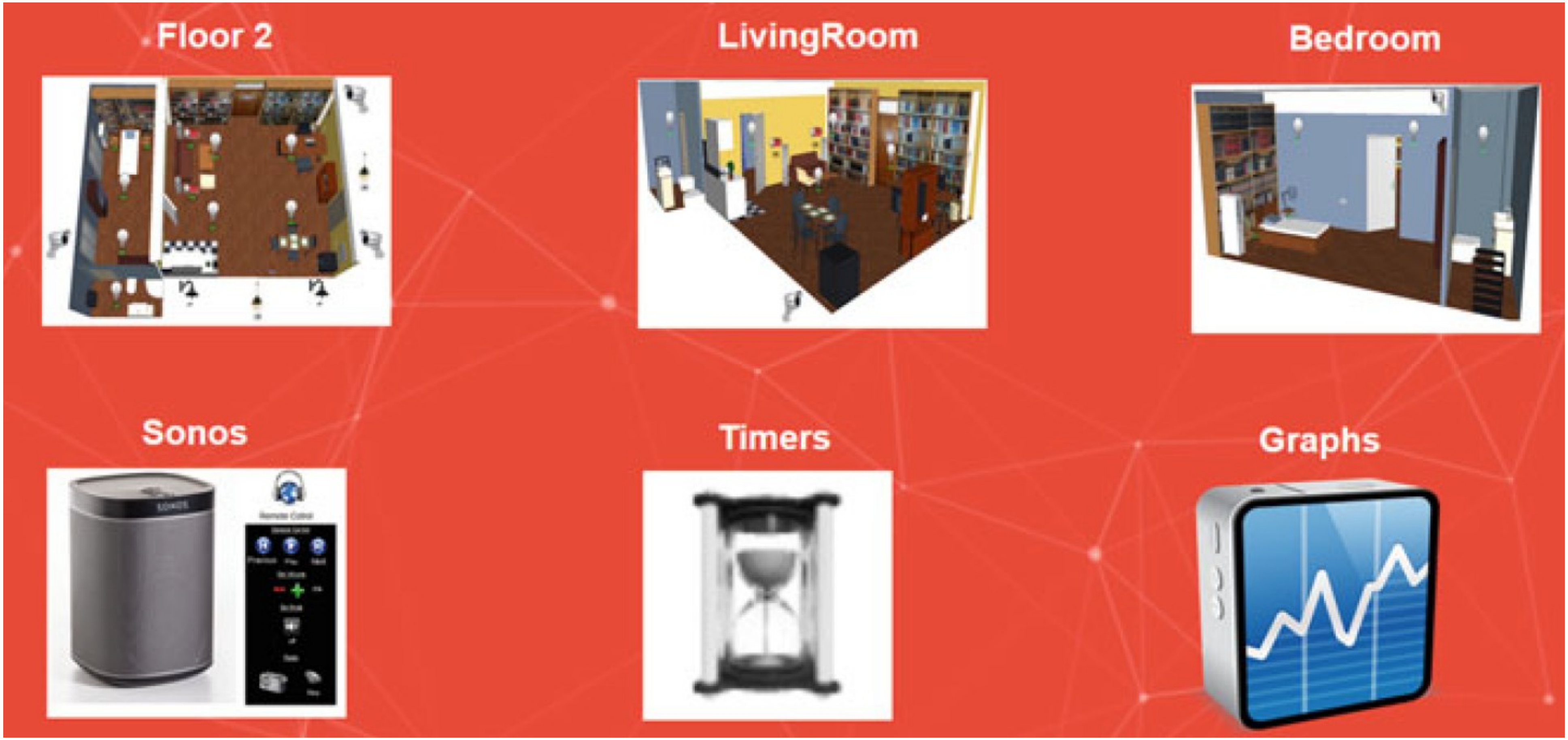

Ambient Assisted Living Residence

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Yïci, et al. 2020, IEEE Xplore 978-1-7281-6728-2/20

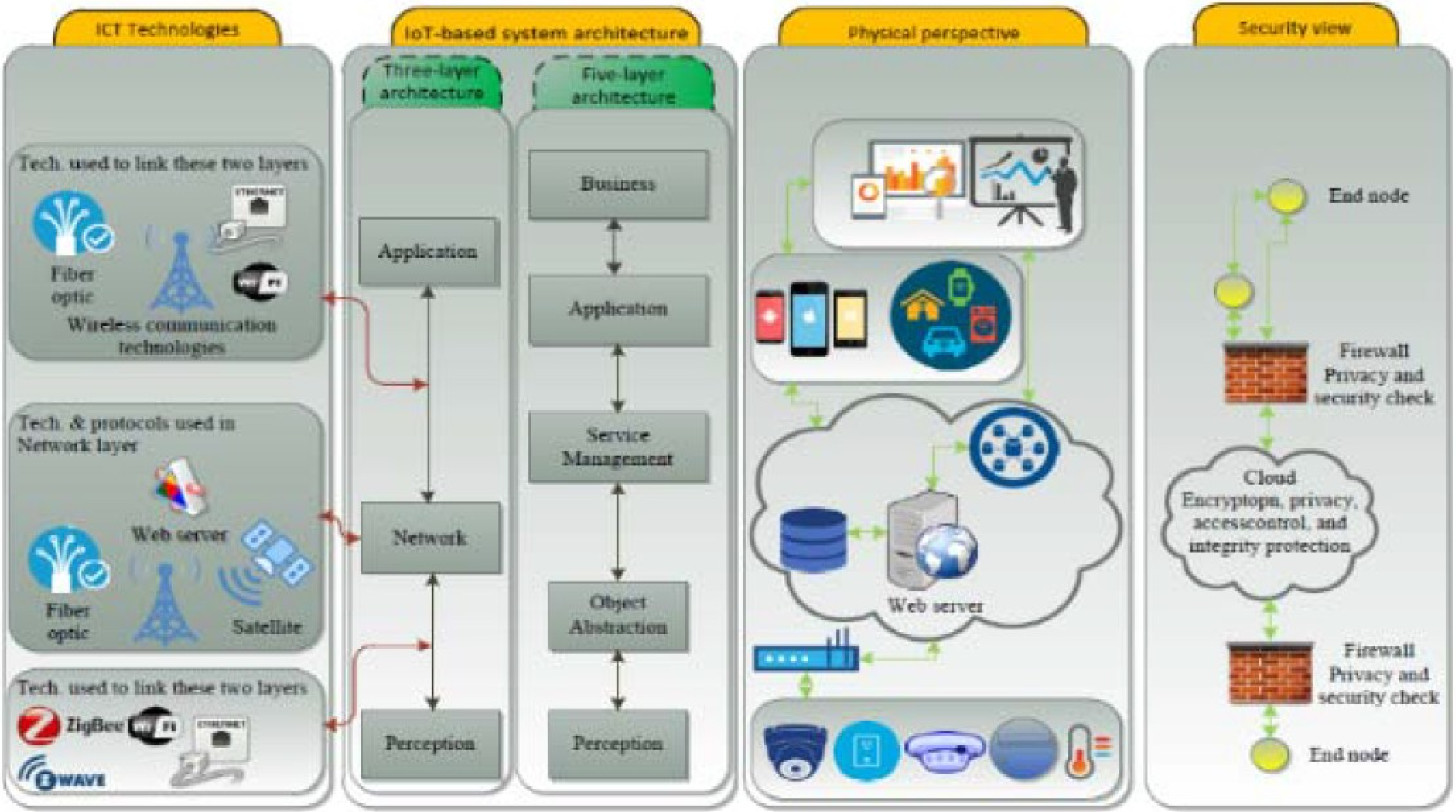

Fig. 1. IoT-based system architecture [4].

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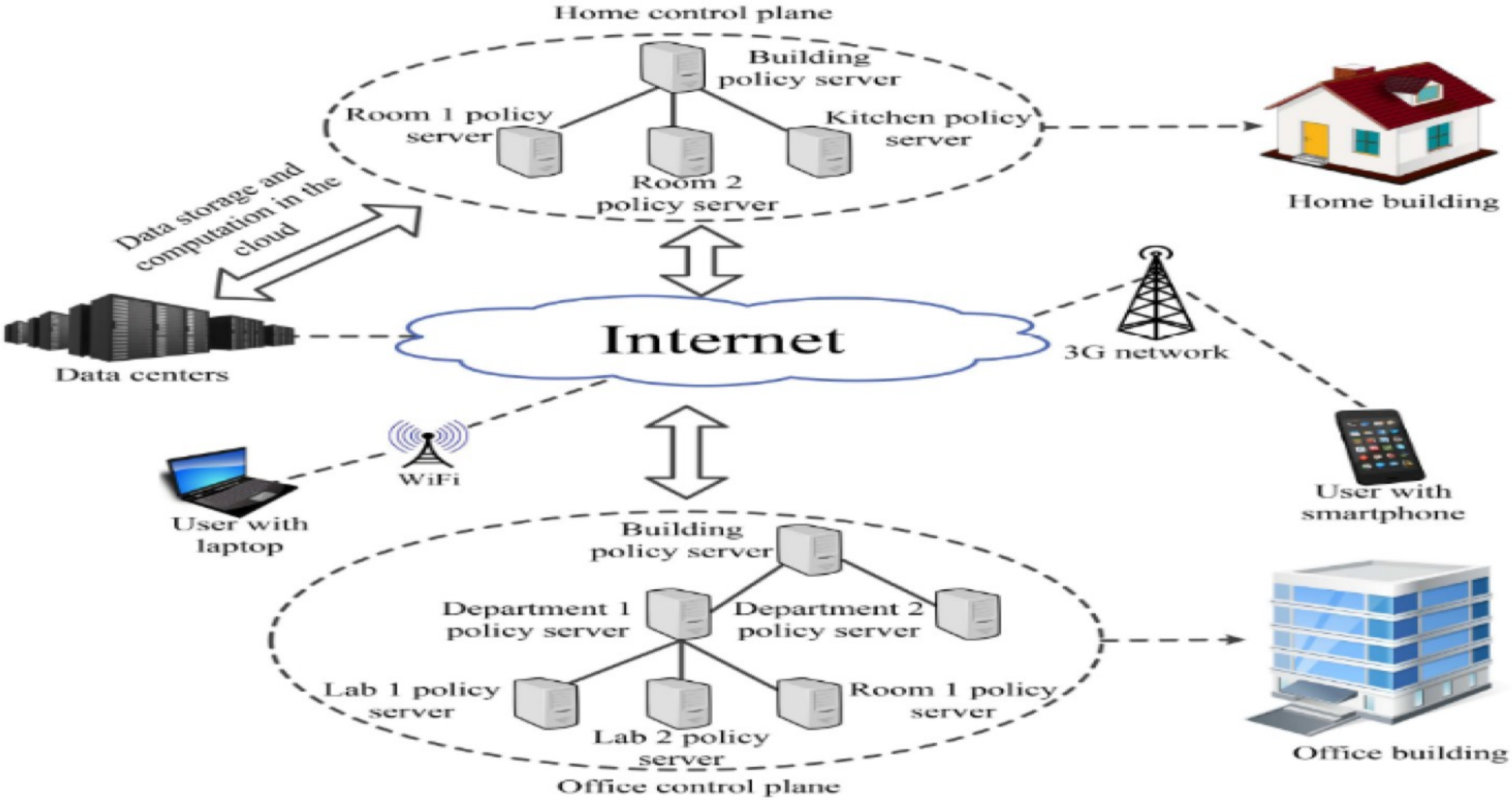

Fig. 2. Smart location-based automated energy control IoT framework for energy efficiency [6].

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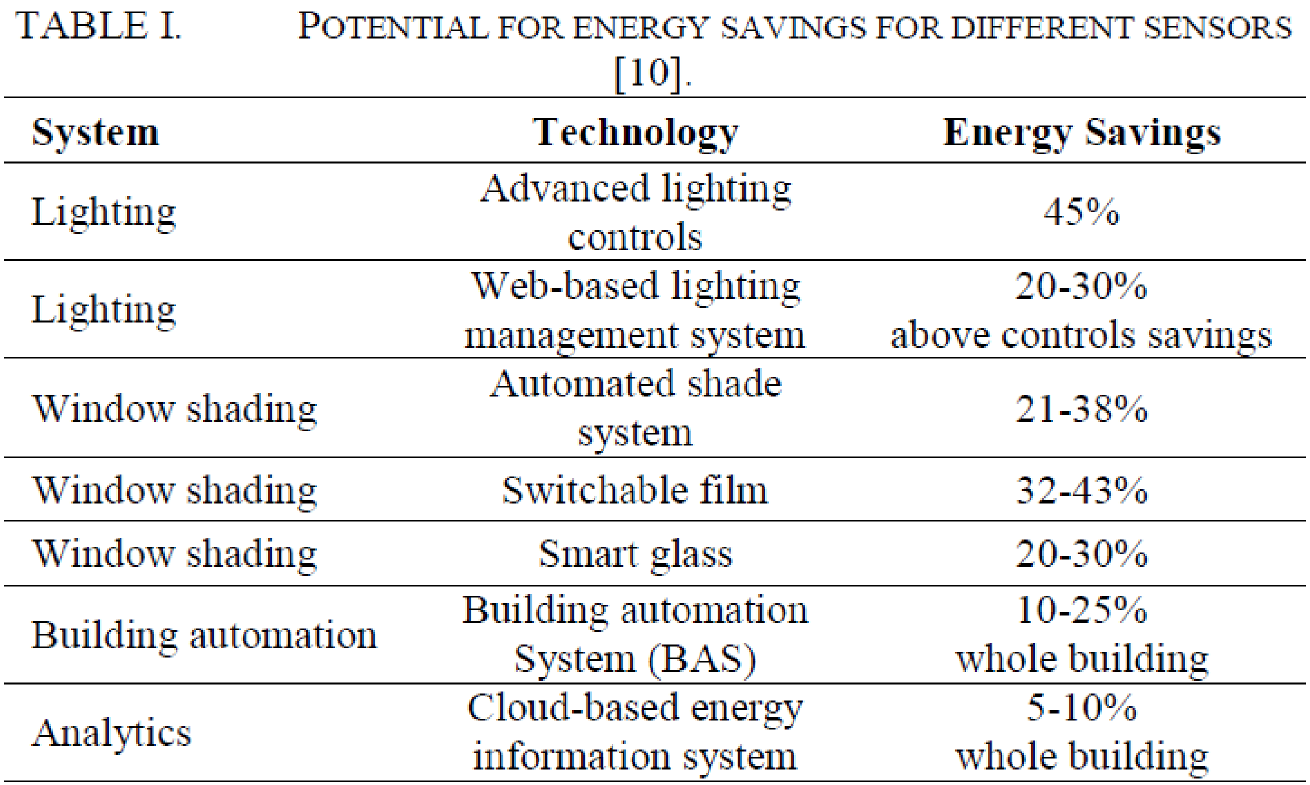

TABLE I. POTENTIAL FOR ENERGY SAVINGS FOR DIFFERENT SENSORS [10].

System	Technology	Energy Savings
Lighting	Advanced lighting controls	45%
Lighting	Web-based lighting management system	20-30% above controls savings
Window shading	Automated shade system	21-38%
Window shading	Switchable film	32-43%
Window shading	Smart glass	20-30%
Building automation	Building automation System (BAS)	10-25% whole building
Analytics	Cloud-based energy information system	5-10% whole building

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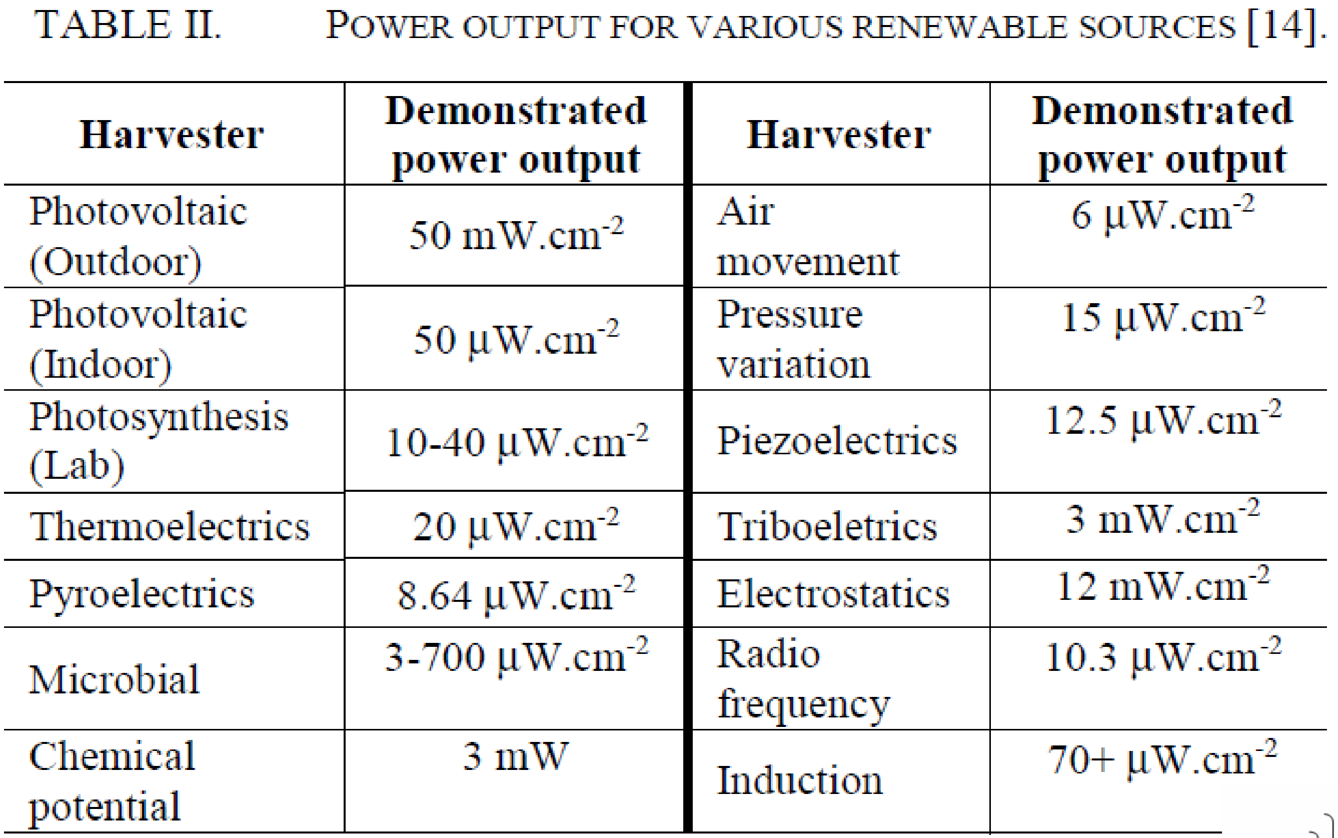
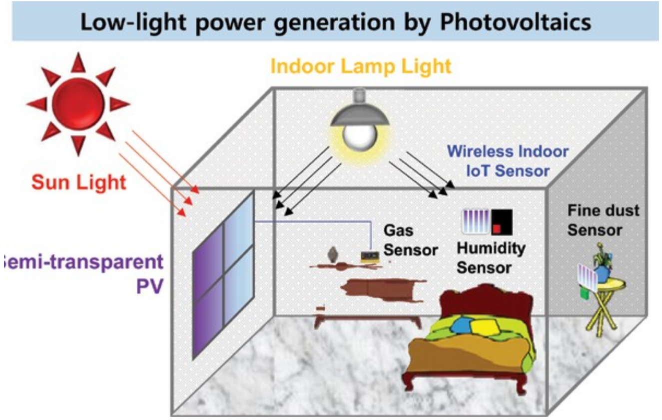
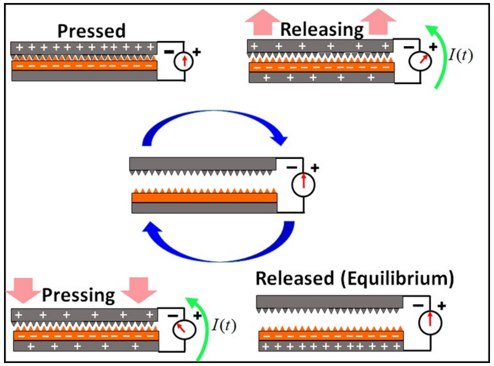
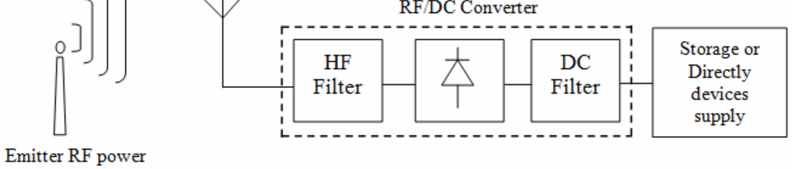


TABLE II. POWER OUTPUT FOR VARIOUS RENEWABLE SOURCES [14].

Harvester	Demonstrated power output	Harvester	Demonstrated power output
Photovoltaic (Outdoor)	50 mW.cm^{-2}	Air movement	6 µW.cm^{-2}
Photovoltaic (Indoor)	50 µW.cm^{-2}	Pressure variation	15 µW.cm^{-2}
Photosynthesis (Lab)	10-40 µW.cm^{-2}	Piezoelectrics	12.5 µW.cm^{-2}
Thermoelectrics	20 µW.cm^{-2}	Triboeletrics	3 mW.cm^{-2}
Pyroelectrics	8.64 µW.cm^{-2}	Electrostatics	12 mW.cm^{-2}
Microbial	3-700 µW.cm^{-2}	Radio frequency	10.3 µW.cm^{-2}
Chemical potential	3 mW	Induction	70+ µW.cm^{-2}







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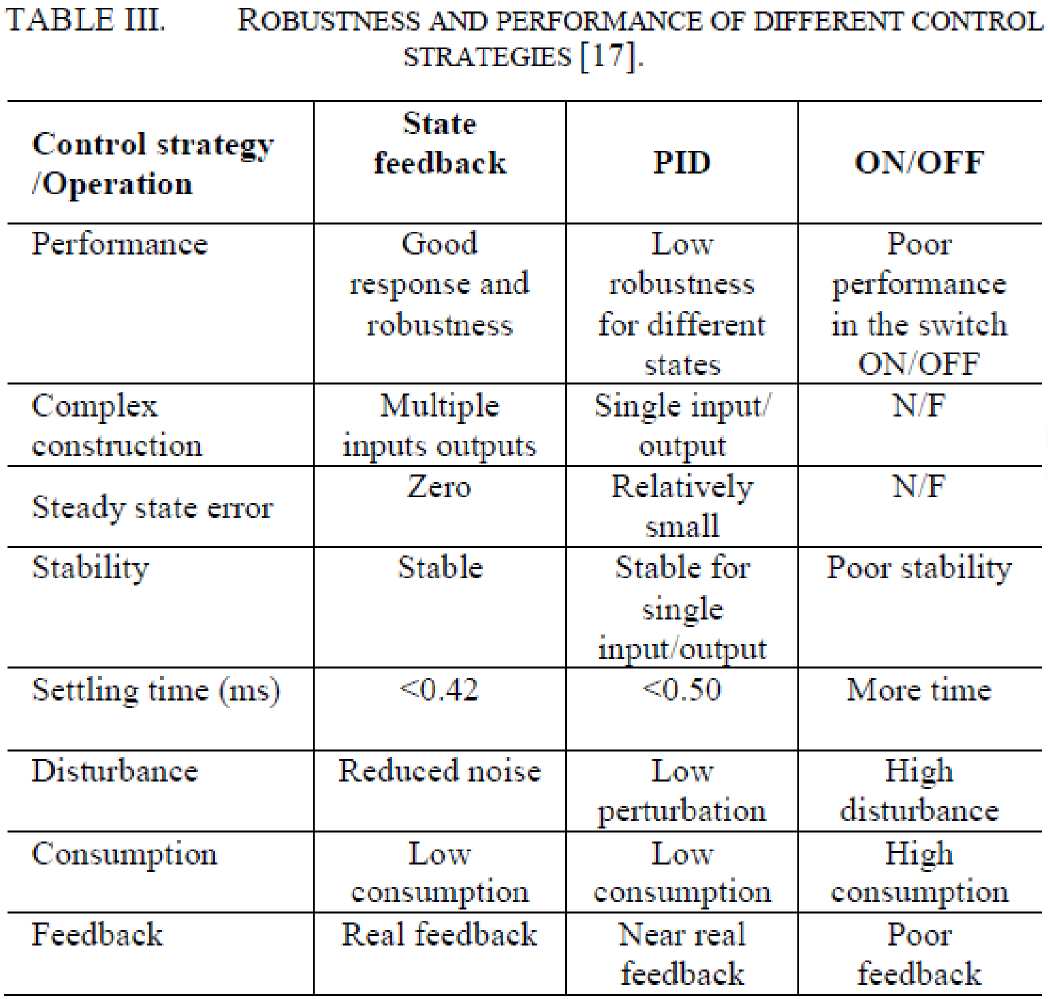
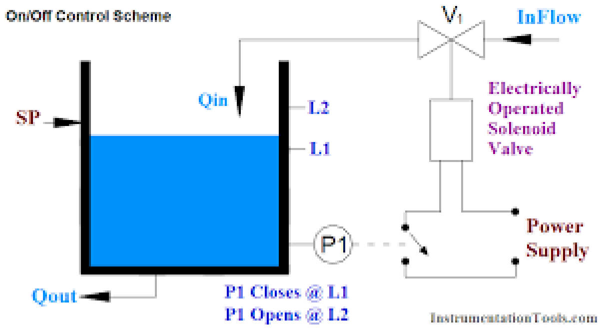
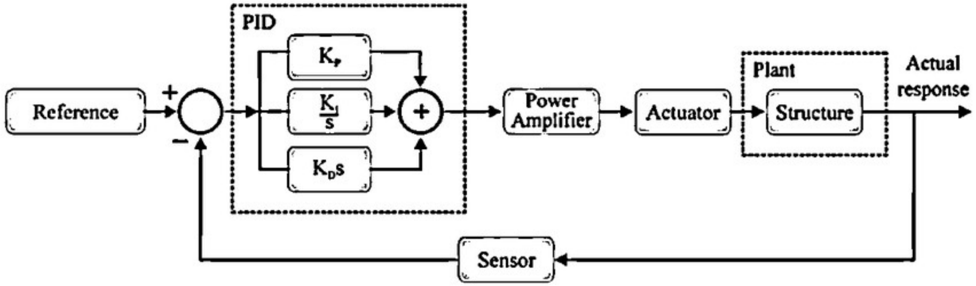
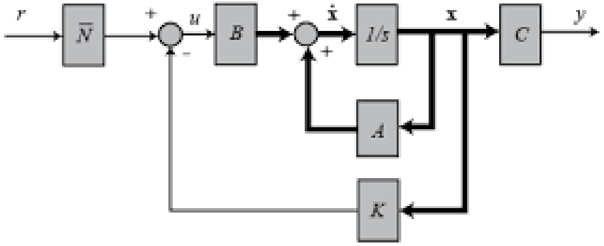


TABLE III. ROBUSTNESS AND PERFORMANCE OF DIFFERENT CONTROL STRATEGIES [17].

Control strategy /Operation	State feedback	PID	ON/OFF
Performance	Good response and robustness	Low robustness for different states	Poor performance in the switch ON/OFF
Complex construction	Multiple inputs outputs	Single input/ output	N/F
Steady state error	Zero	Relatively small	N/F
Stability	Stable	Stable for single input/output	Poor stability
Settling time (ms)	<0.42	<0.50	More time
Disturbance	Reduced noise	Low perturbation	High disturbance
Consumption	Low consumption	Low consumption	High consumption
Feedback	Real feedback	Near real feedback	Poor feedback







- Observador de perturbações
- Estimativa de ocupação

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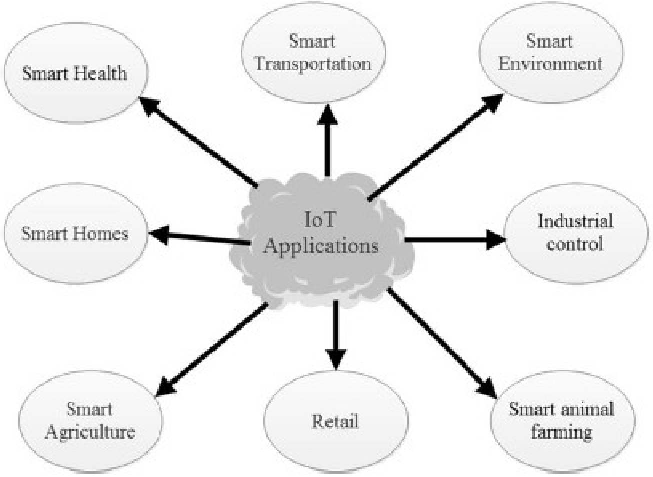

Fig. 1 Applications of Internet of Things

Fig. 3 Smart home scenario

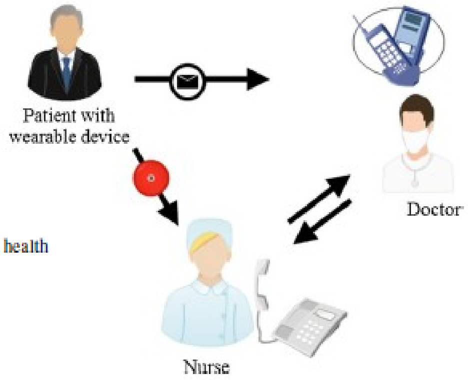

Fig. 2 Example of a smart health scenario

Fig. 4 Smart vehicular environment

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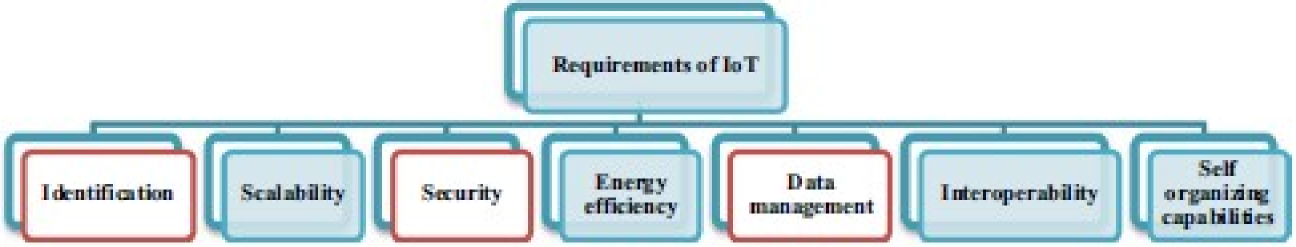

Fig. 5 Requirements of IoT

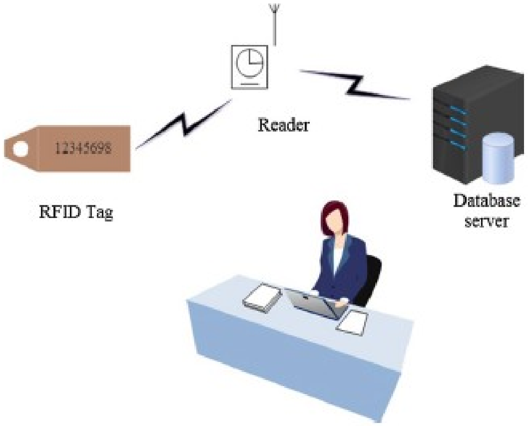

Fig. 6 Components of an RFID based IoT Application

Fig. 7 Example scenario of sensors deployed in battlefield

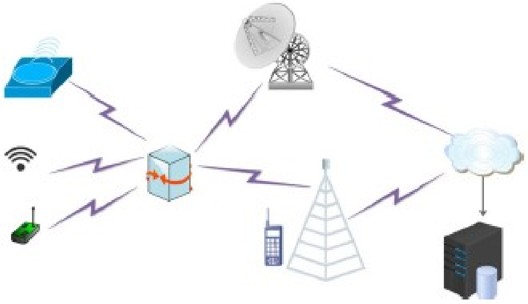

Fig. 8 Components of M2M communication

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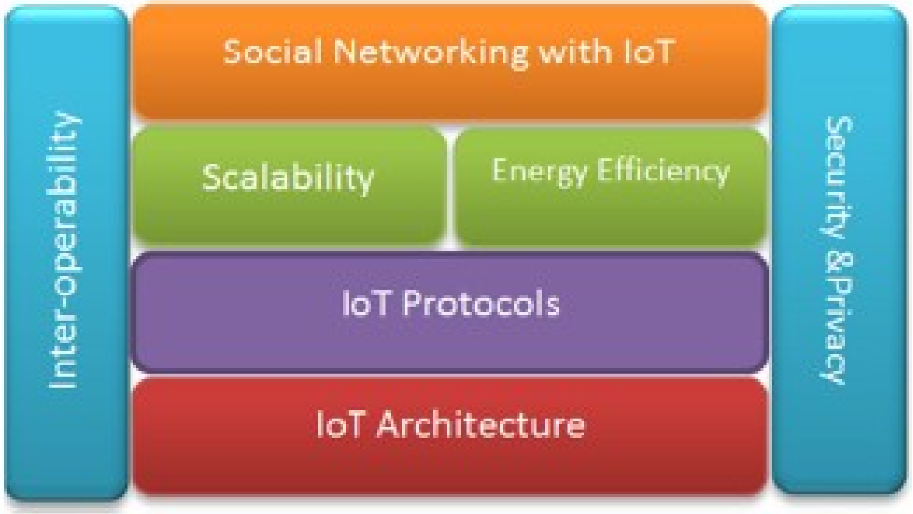

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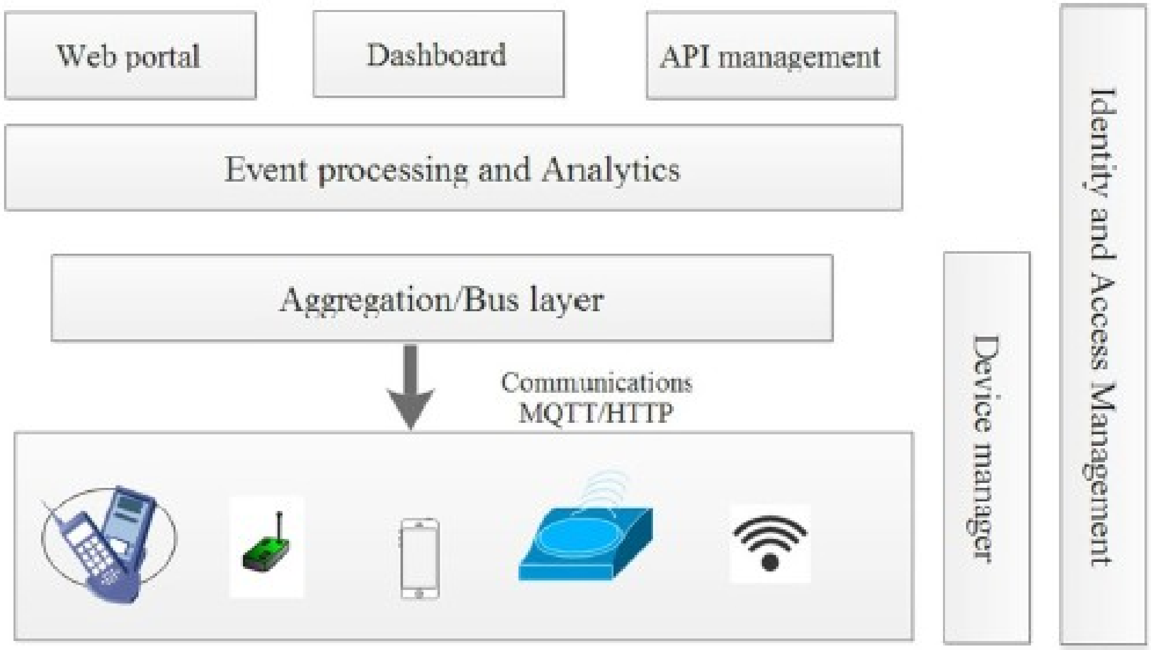

Fig. 13 Reference architecture for IoT proposed in [41]

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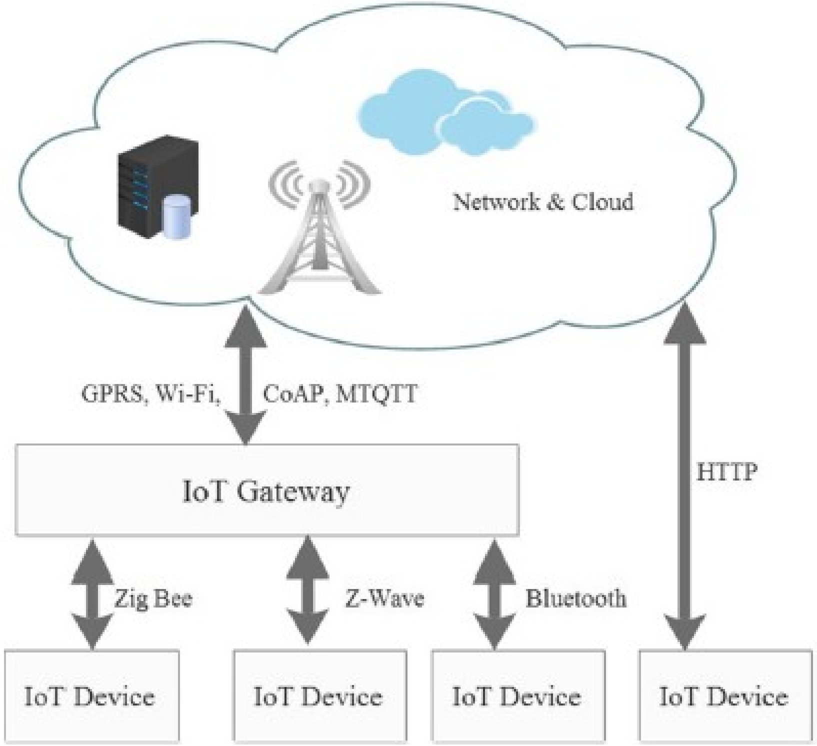

Fig. 14 Example of IoT gateway

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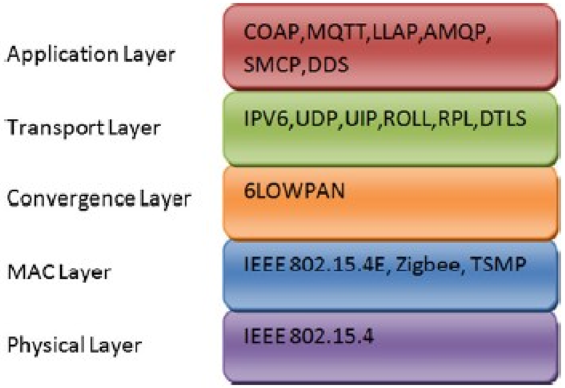
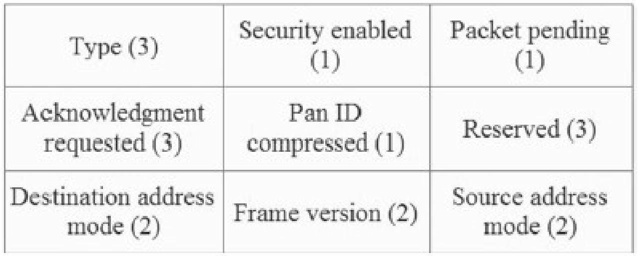
Fig. 15 Protocol stack



Application Layer	COAP,MQTT,LLAP,AMQP, SMCP,DDS
Transport Layer	IPV6,UDP,UIP,ROLL,RPL,DTLS
Convergence Layer	6LOWPAN
MAC Layer	IEEE 802.15.4E, Zigbee, TSMP
Physical Layer	IEEE 802.15.4

Fig. 16 IEEE802.15.4-2006 header [3]



Type (3)	Security enabled (1)	Packet pending (1)
Acknowledgment requested (3)	Pan ID compressed (1)	Reserved (3)
Destination address mode (2)	Frame version (2)	Source address mode (2)

Fig. 17 XBee Series 2/ZigBee

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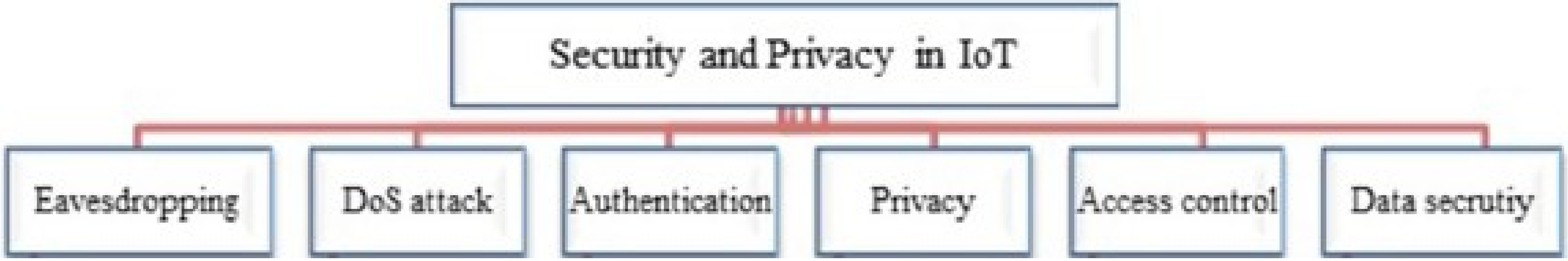

Fig. 18 Various Security Attacks in IoT

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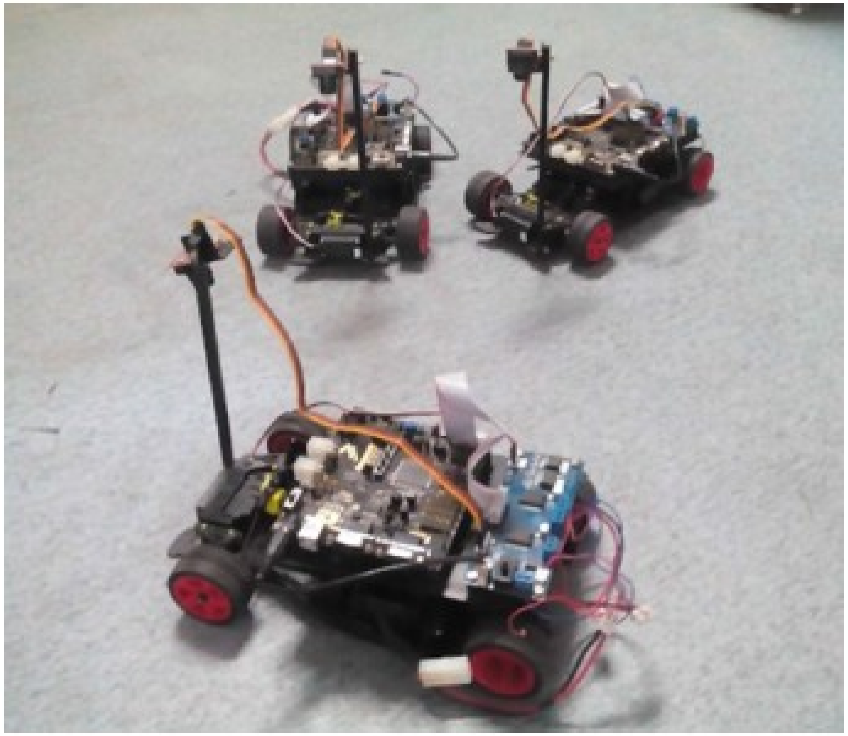
Fig. 19 Example of real testbed developed [70]



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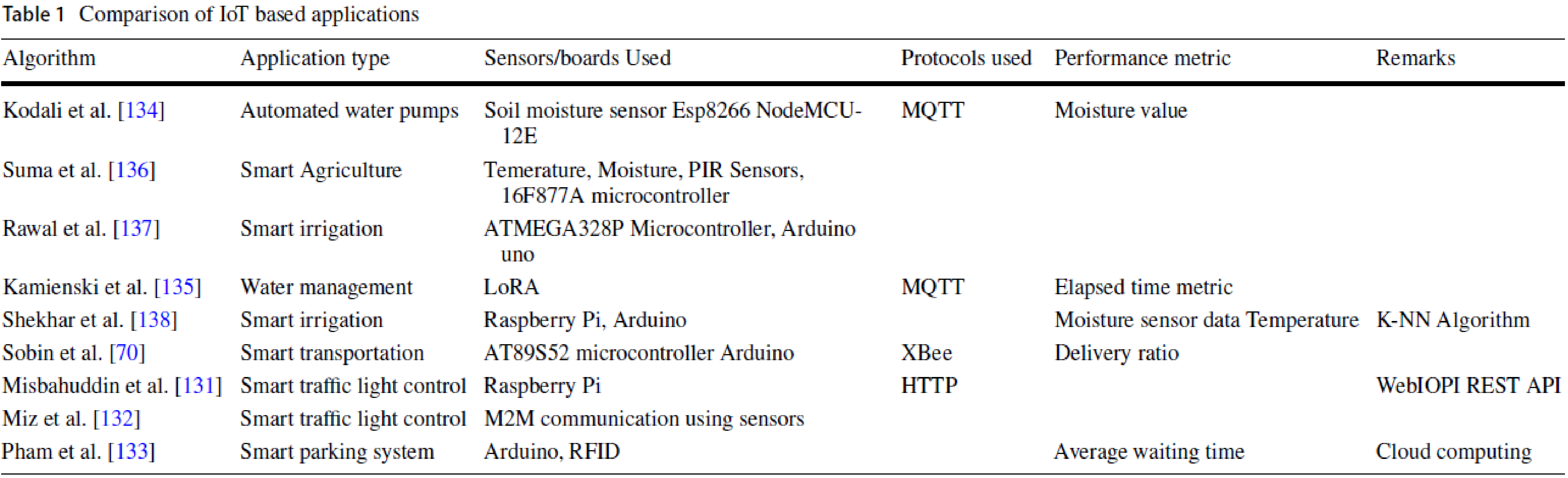

Table 1 Comparison of IoT based applications

Algorithm	Application type	Sensors/boards Used	Protocols used	Performance metric	Remarks
Kodali et al. [134]	Automated water pumps	Soil moisture sensor Esp8266 NodeMCU-12E	MQTT	Moisture value	
Suma et al. [136]	Smart Agriculture	Temerature, Moisture, PIR Sensors, 16F877A microcontroller			
Rawal et al. [137]	Smart irrigation	ATMEGA328P Microcontroller, Arduino uno			
Kamienski et al. [135]	Water management	LoRA	MQTT	Elapsed time metric	
Shekhar et al. [138]	Smart irrigation	Raspberry Pi, Arduino		Moisture sensor data Temperature	K-NN Algorithm
Sobin et al. [70]	Smart transportation	AT89S52 microcontroller Arduino	XBee	Delivery ratio	
Misbahuddin et al. [131]	Smart traffic light control	Raspberry Pi	HTTP		WebIOPI REST API
Miz et al. [132]	Smart traffic light control	M2M communication using sensors			
Pham et al. [133]	Smart parking system	Arduino, RFID		Average waiting time	Cloud computing

A Comprehensive Study of IoT and WSN MAC Protocols: Research Issues, Challenges and Opportunities Kumar et al. 2018, IEEE Access

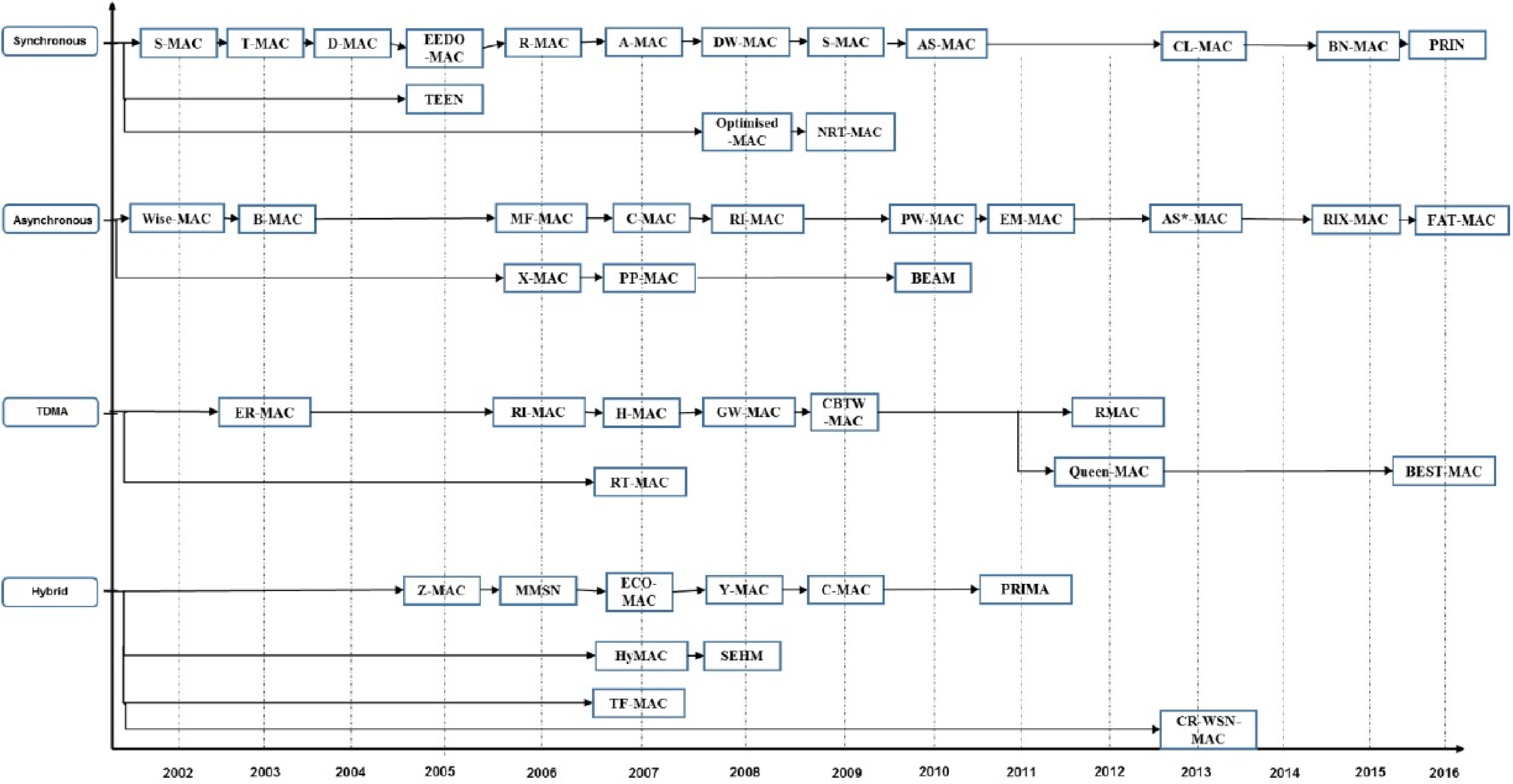

Figure 2. Taxonomy of WSN MAC protocols.

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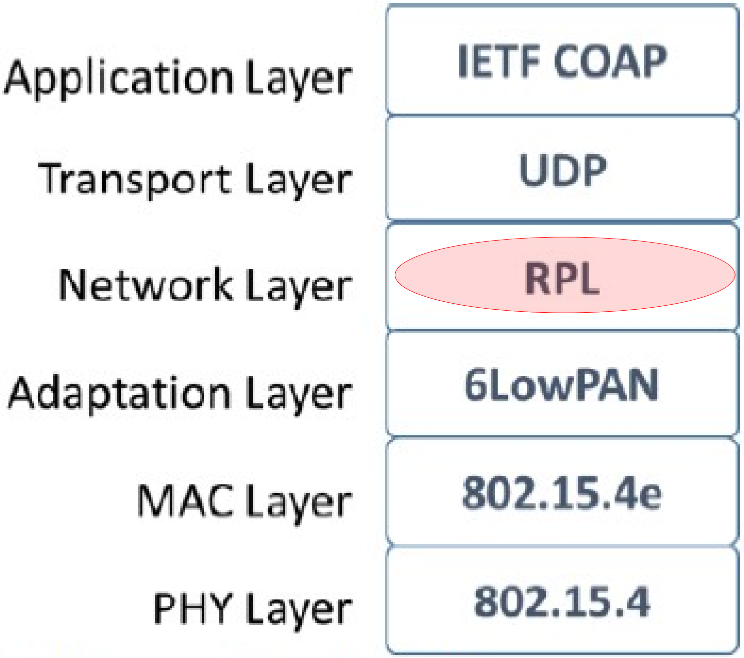

Figure 3. **Standardized protocol stacks for IoT.**

RPL – IPv6 Routing Protocol for Low Power and Lossy Networks

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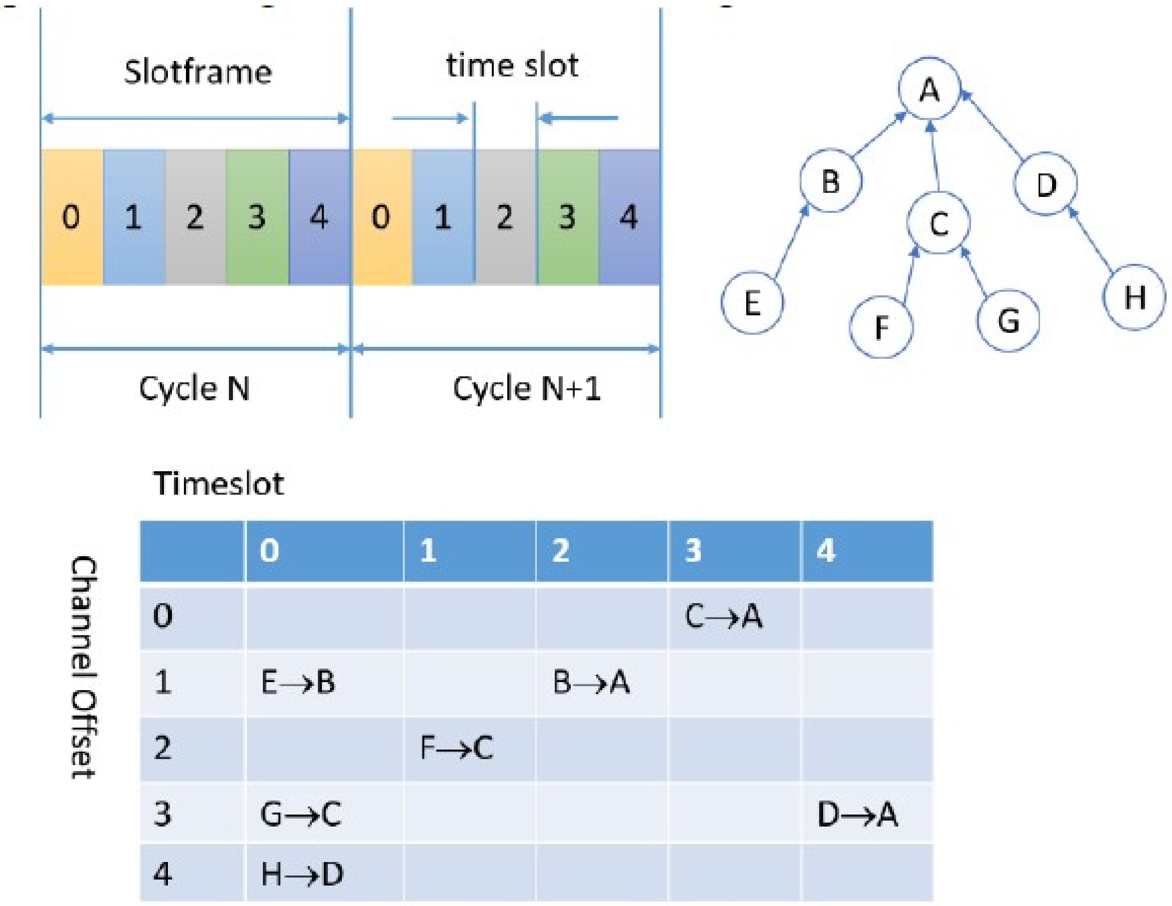

	0	1	2	3	4
0				C→A	
1	E→B		B→A		
2		F→C			
3	G→C				D→A
4	H→D				

Figure 4. TSCH slot frame, and a sample tree-topology network with a possible link schedule for data collection.

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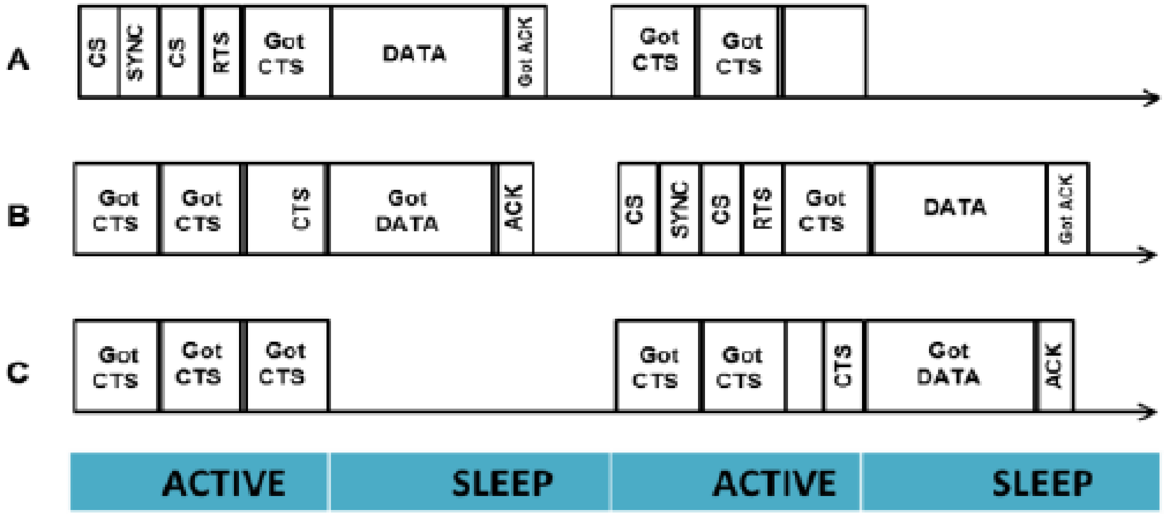

Figure 6. An example of duty-cycling in S-MAC, and data transmission from node A to node B followed by from node B to node C.

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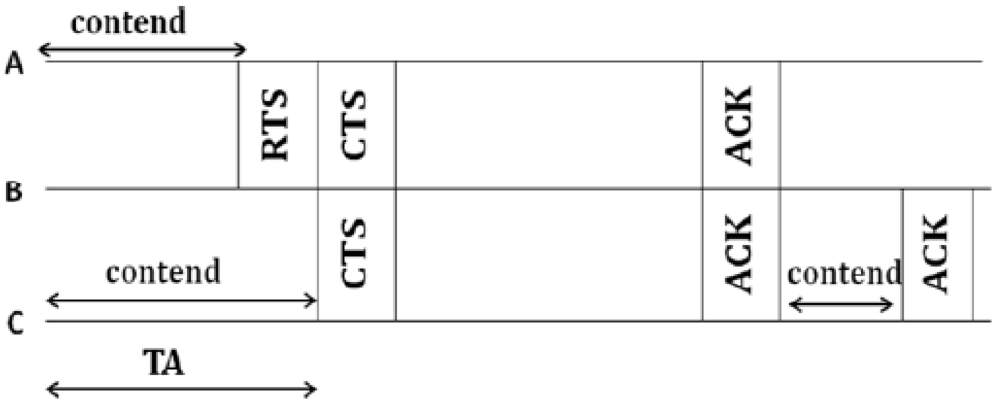


Figure 7. DATA exchange between nodes A, B and C. Node C can overhear the CTS from node B, and it does not affect the transmission between Node A and Node B. TA for C need to be long enough so that it can receive the beginning phase of the CTS.

Assynchronous

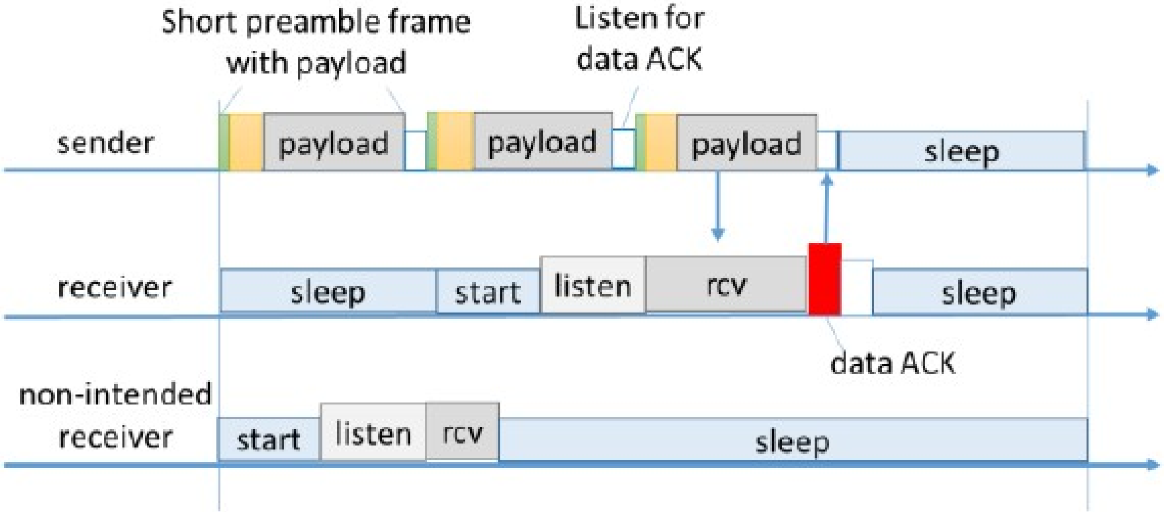
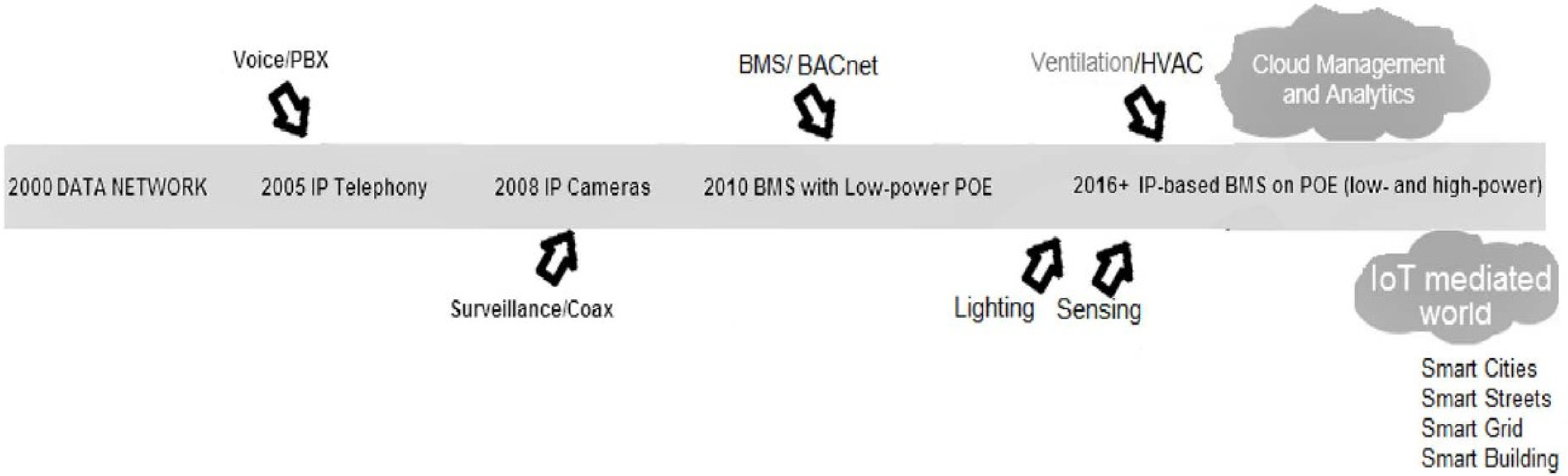


Figure 24. BEAM using Short Preambles with Payload.

IoT Considerations, Requirements, and Architectures for Smart Buildings—Energy Optimization and Next-Generation Building Management Systems

Minoli et al. IEEE Internet of Things Journal, Vol. 4, No 1, Feb 2017



Note: BACnet is an ASHRAE, ANSI, and ISO 16484-5 standard communications protocol for building automation and control (BACnet was subsumed in ASHRAE/ANSI Standard 135 in 1995, and in ISO 16484-5 in 2003.) The BACnet protocol defines several services that are used to communicate between control devices typically utilized in building (including HVAC, lighting control, access control, and fire detection systems). It specifies a number of network, data link, and physical layer protocols, including but not limited to standards such as IP/Ethernet.

Fig. 2. Graphical representation of technology convergence of building-support systems in recent years.

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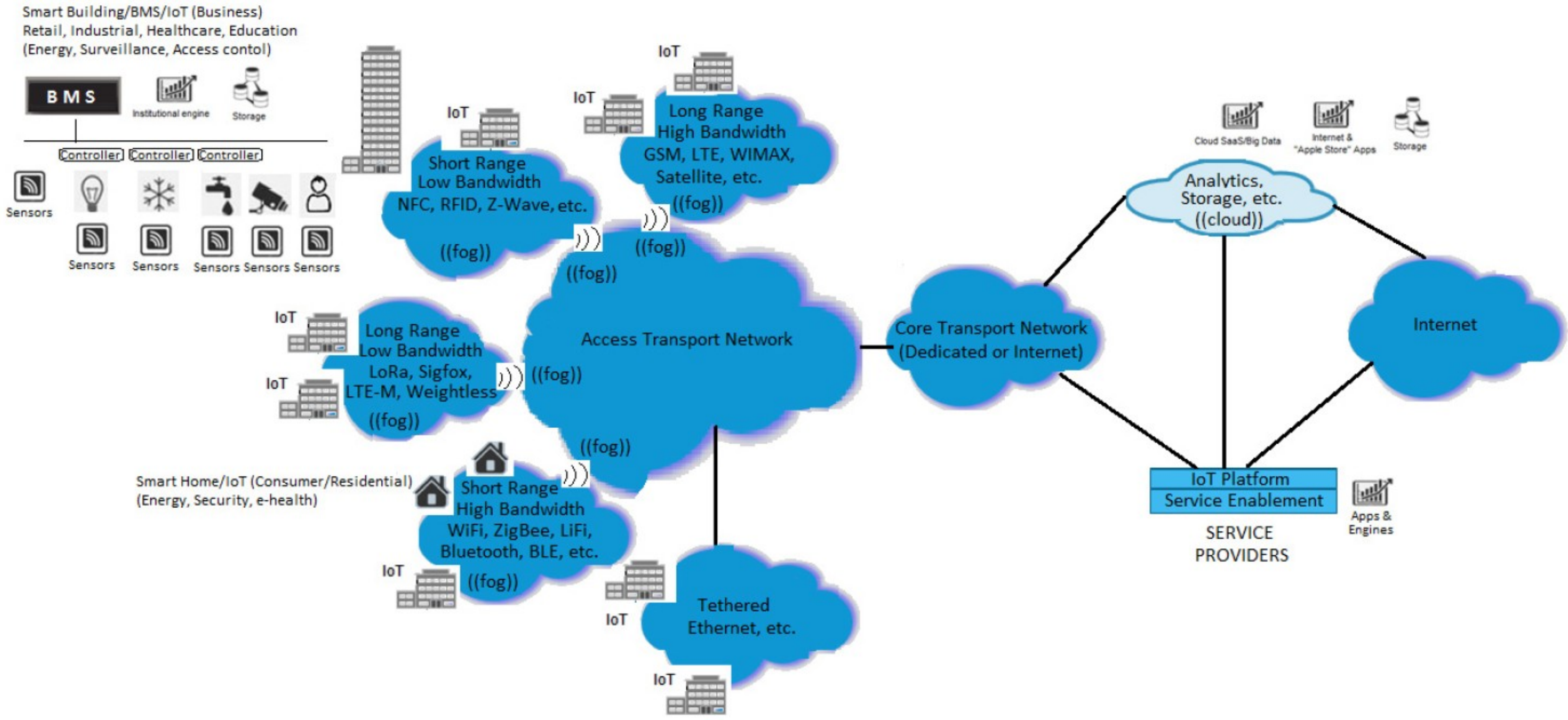

Fig. 3. IoT environment showing sensors, BMSs, aggregation networks, and cloud services.

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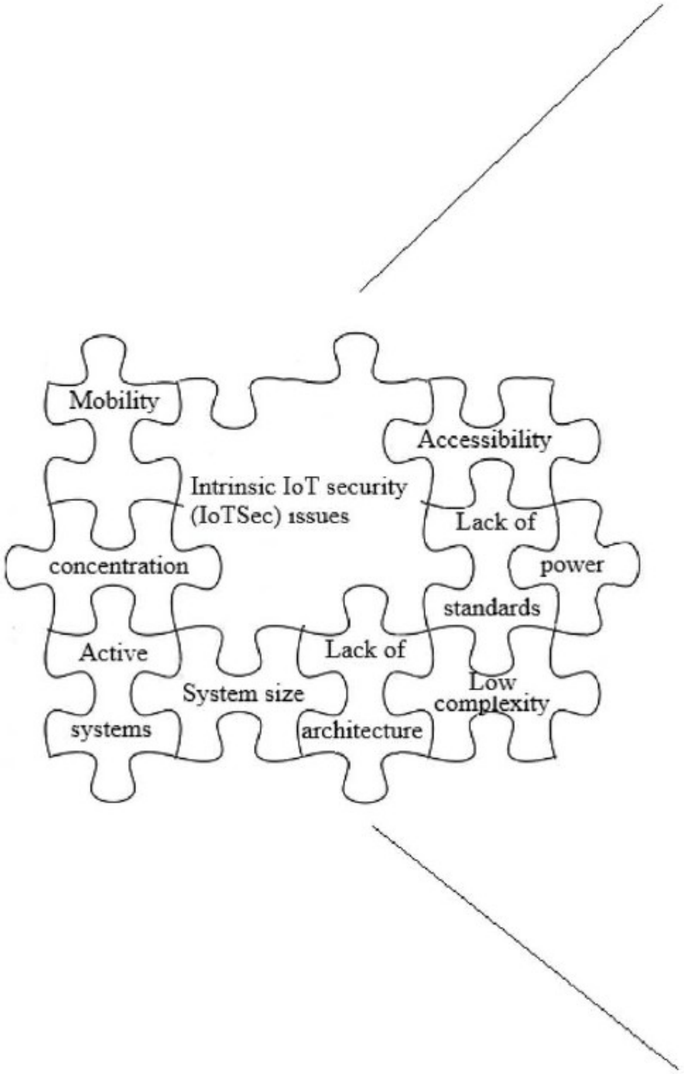

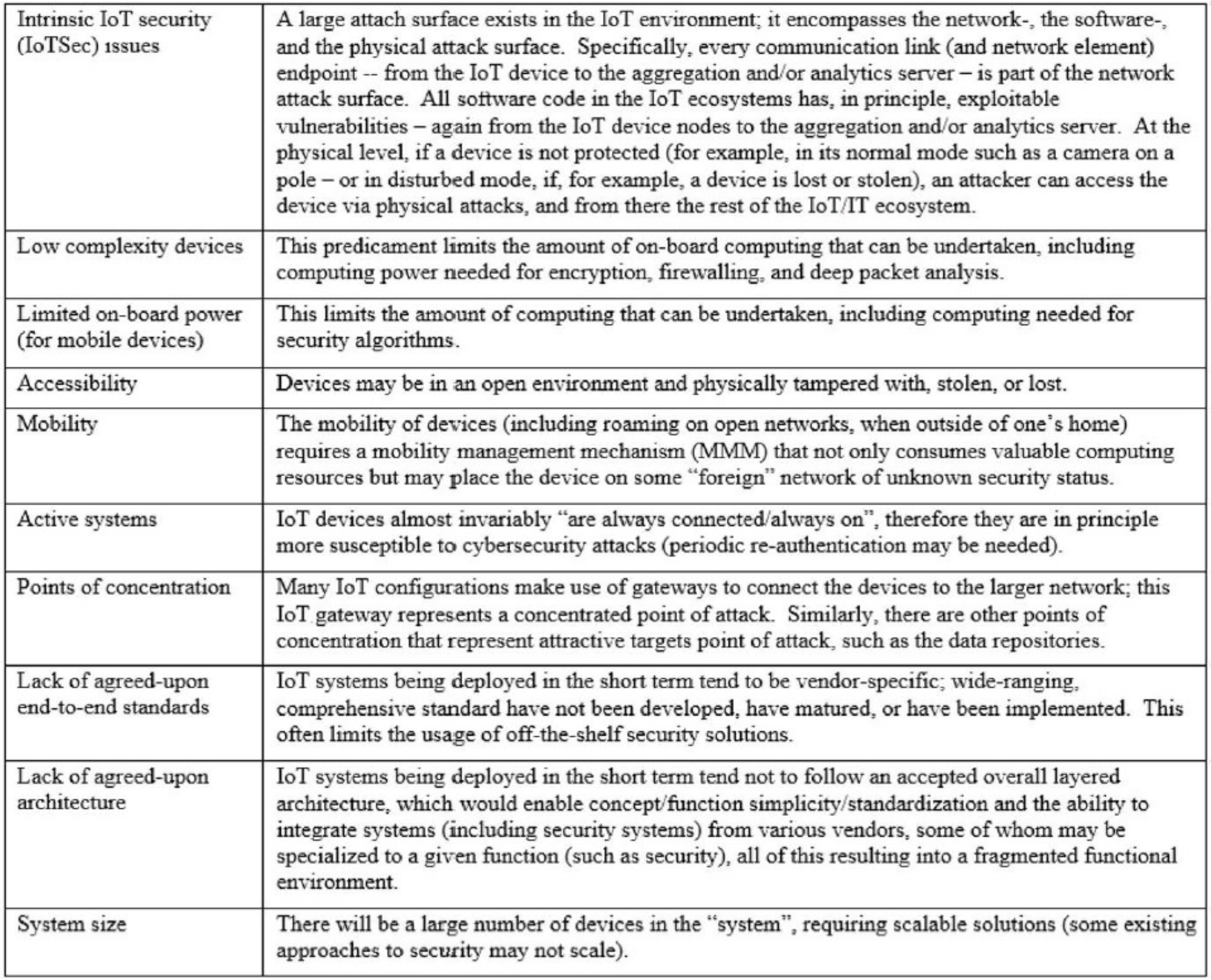

Intrinsic IoT security (IoTSec) issues	A large attach surface exists in the IoT environment; it encompasses the network-, the software-, and the physical attack surface. Specifically, every communication link (and network element) endpoint -- from the IoT device to the aggregation and/or analytics server – is part of the network attack surface. All software code in the IoT ecosystems has, in principle, exploitable vulnerabilities – again from the IoT device nodes to the aggregation and/or analytics server. At the physical level, if a device is not protected (for example, in its normal mode such as a camera on a pole – or in disturbed mode, if, for example, a device is lost or stolen), an attacker can access the device via physical attacks, and from there the rest of the IoT/IT ecosystem.
Low complexity devices	This predicament limits the amount of on-board computing that can be undertaken, including computing power needed for encryption, firewalling, and deep packet analysis.
Limited on-board power (for mobile devices)	This limits the amount of computing that can be undertaken, including computing needed for security algorithms.
Accessibility	Devices may be in an open environment and physically tampered with, stolen, or lost.
Mobility	The mobility of devices (including roaming on open networks, when outside of one's home) requires a mobility management mechanism (MMM) that not only consumes valuable computing resources but may place the device on some "foreign" network of unknown security status.
Active systems	IoT devices almost invariably "are always connected/always on", therefore they are in principle more susceptible to cybersecurity attacks (periodic re-authentication may be needed).
Points of concentration	Many IoT configurations make use of gateways to connect the devices to the larger network; this IoT gateway represents a concentrated point of attack. Similarly, there are other points of concentration that represent attractive targets point of attack, such as the data repositories.
Lack of agreed-upon end-to-end standards	IoT systems being deployed in the short term tend to be vendor-specific; wide-ranging, comprehensive standard have not been developed, have matured, or have been implemented. This often limits the usage of off-the-shelf security solutions.
Lack of agreed-upon architecture	IoT systems being deployed in the short term tend not to follow an accepted overall layered architecture, which would enable concept/function simplicity/standardization and the ability to integrate systems (including security systems) from various vendors, some of whom may be specialized to a given function (such as security), all of this resulting into a fragmented functional environment.
System size	There will be a large number of devices in the "system", requiring scalable solutions (some existing approaches to security may not scale).

Fig. 6. Challenges impacting deployment of IoT in general and in the smart building arena in particular.

IoT Considerations...

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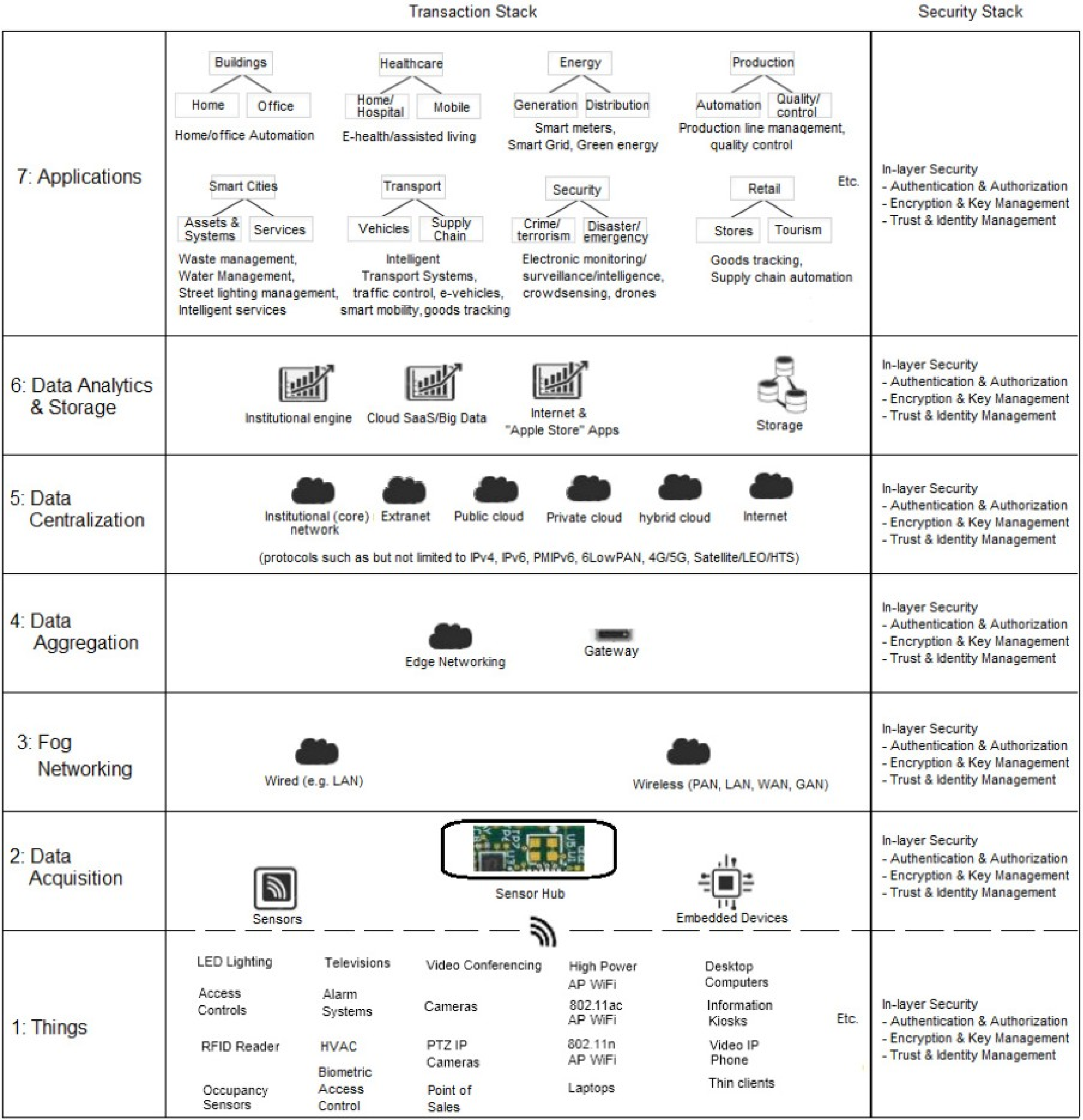

	Transaction Stack	Security Stack
7: Applications	Buildings: Home, Office Home/office Automation Healthcare: Home/Hospital, Mobile E-health/assisted living Energy: Generation, Distribution Smart meters, Smart Grid, Green energy Production: Automation, Quality/control Production line management, quality control Smart Cities: Assets & Systems, Services Waste management, Water Management, Street lighting management, Intelligent services Transport: Vehicles, Supply Chain Intelligent Transport Systems, traffic control, e-vehicles, smart mobility, goods tracking Security: Crime/terrorism, Disaster/emergency Electronic monitoring/surveillance/intelligence, crowdsensing, drones Retail: Stores, Tourism Goods tracking, Supply chain automation Etc.	In-layer Security - Authentication & Authorization - Encryption & Key Management - Trust & Identity Management
6: Data Analytics & Storage	Institutional engine Cloud SaaS/Big Data Internet & "Apple Store" Apps Storage	In-layer Security - Authentication & Authorization - Encryption & Key Management - Trust & Identity Management
5: Data Centralization	Institutional (core) network Extranet Public cloud Private cloud hybrid cloud Internet (protocols such as but not limited to IPv4, IPv6, PMIPv6, 6LowPAN, 4G/5G, Satellite/LEO/HTS)	In-layer Security - Authentication & Authorization - Encryption & Key Management - Trust & Identity Management
4: Data Aggregation	Edge Networking Gateway	In-layer Security - Authentication & Authorization - Encryption & Key Management - Trust & Identity Management
3: Fog Networking	Wired (e.g. LAN) Wireless (PAN, LAN, WAN, GAN)	In-layer Security - Authentication & Authorization - Encryption & Key Management - Trust & Identity Management
2: Data Acquisition	Sensors Sensor Hub Embedded Devices	In-layer Security - Authentication & Authorization - Encryption & Key Management - Trust & Identity Management
1: Things	LED Lighting Access Controls RFID Reader Occupancy Sensors Televisions Alarm Systems HVAC Biometric Access Control Video Conferencing Cameras PTZ IP Cameras Point of Sales High Power AP WiFi 802.11ac AP WiFi 802.11n AP WiFi Laptops Desktop Computers Information Kiosks Video IP Phone Thin clients Etc.	In-layer Security - Authentication & Authorization - Encryption & Key Management - Trust & Identity Management

Fig. 7. OSIRM

7th layer: Open System IoT Reference Model