ICIST2018

Interoperability for the sustainability assessment framework in IoT like environments

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Motivation

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- Diversity of IoT devices and heterogeneity of the communication protocols, data formats and service demands for storage, energy, and availability has imposed a huge set of side effect issues that are becoming the serious stumbling stone in IoT-like system design and management.
- Analysis of the IoT technology potentials that would support sustainable and interoperable:
  - economical
  - ecological
  - social
  - and business growth
  - ➢ according to the Multi Objective Cloud Computing Sustainability Assessment Framework
- Interoperability is one of the most persistent issues

IoT connectivity technologies

- Bluetooth Low Energy (BLE)
- WiFi Low Power
- ZigBee
- NFC
- NB-IoT
- SigFox
- Lora
- 3GPP

Short range vs. long range corners

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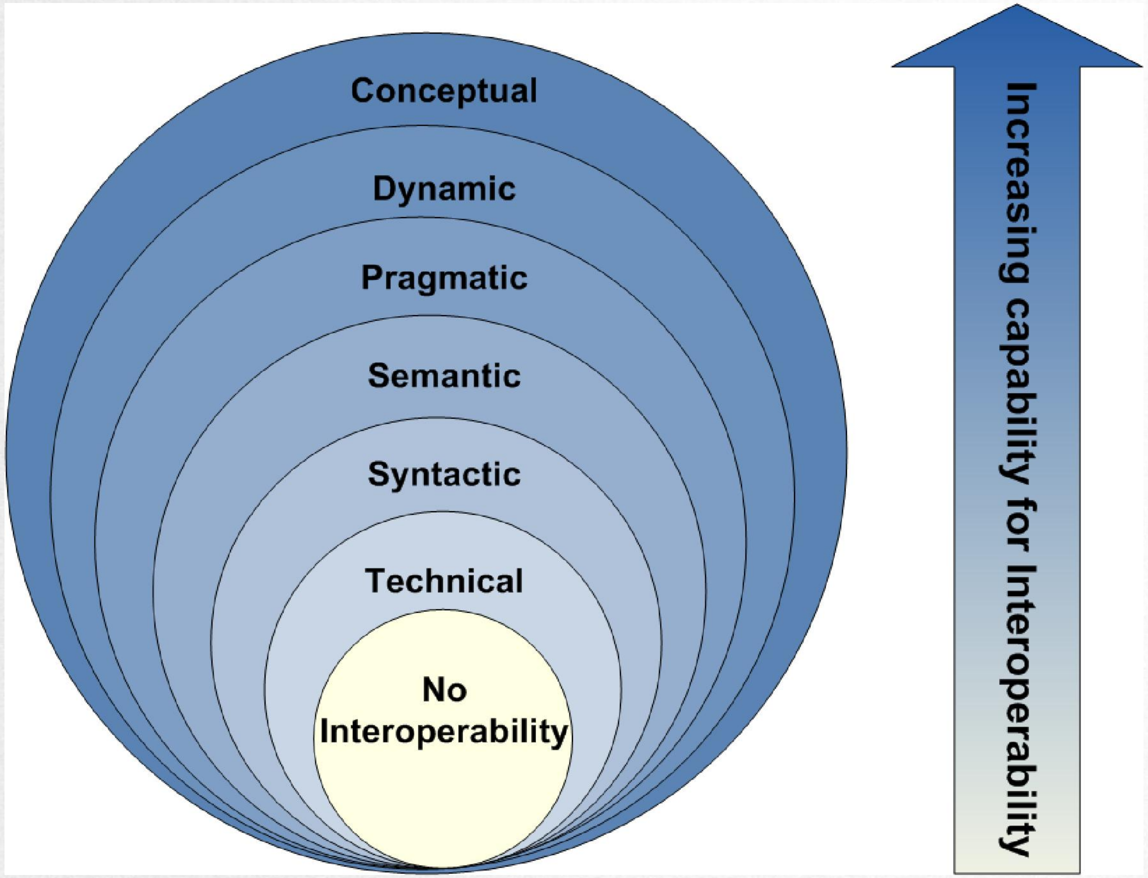
- Short range technologies exploit low cost and low power/energy consumption. Mostly some LAN/PAN technologies: Bluetooth BLE, WiFi, ZigBee
- Long range technologies deal with high cost and high power. Mostly some 3GPP technologies: LTE, CatM/NB-IoT
- LPWAN segment: Sigfox (ultra narrow band), LoRa, NB-IoT
- Industrial IoT devices used for Ind Automation require direct connection to a power supply and high data rates. IoT requires an end-to-end security across the stack.

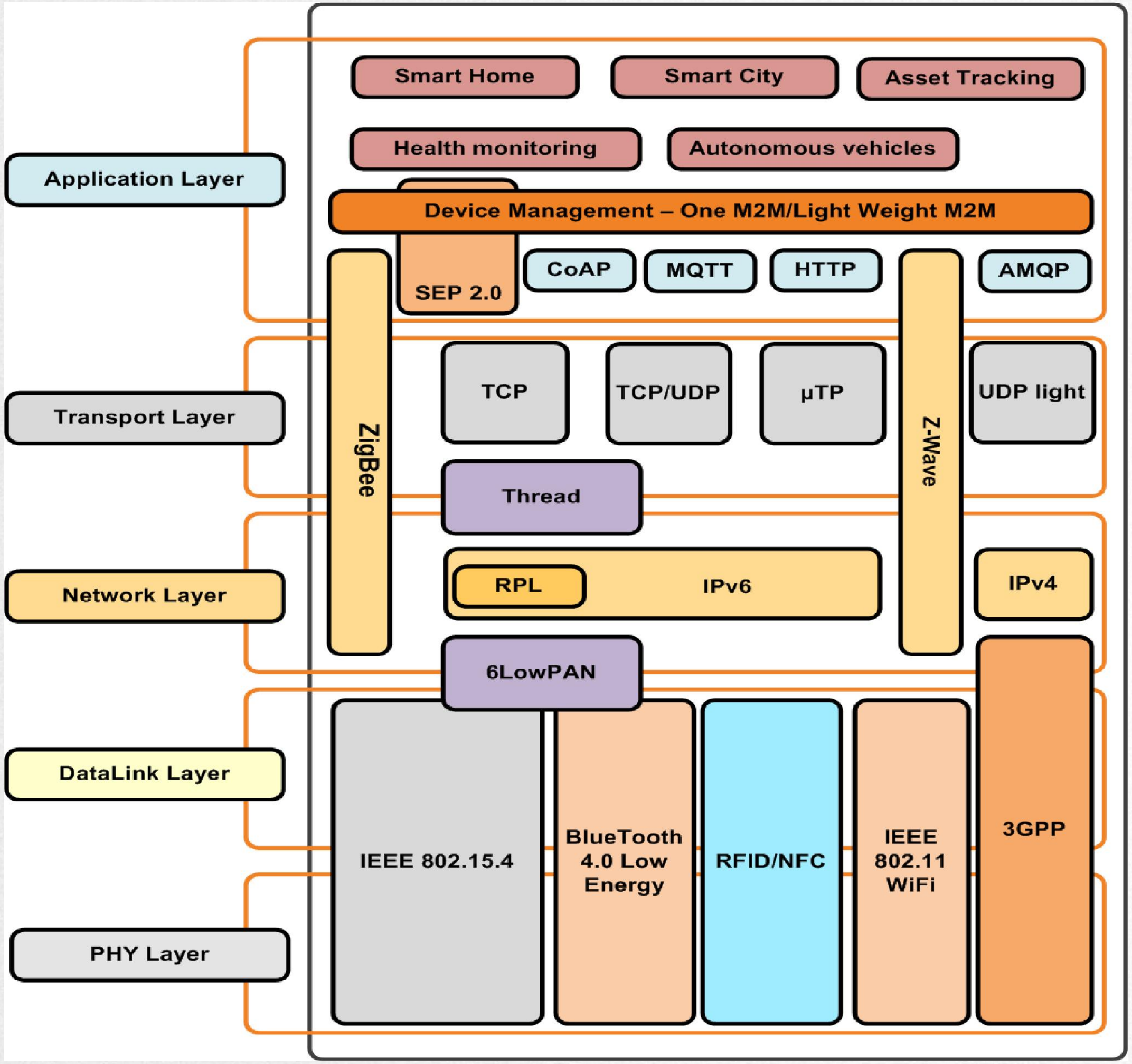
Conceptual interoperability model



- 6 levels of interoperability
- **Technical Interoperability:** associated with hardware/software components, systems and platforms that enable M2M communication. It is centered on protocols and the infrastructure needed for their operation.
- Sustainability needs for open data sources (private, public). The open data paradigm is one of the main cornerstones for interoperable sustainability of the system

Technical interoperability

- TCP/IP protocol stack is a generally accepted concept in system networking and interaction. New tendencies: DASH7 (Low Power Wireless IoT Stack).
- Presently the integration and consolidation of IoT wireless technologies is not apparent.
- System vulnerabilities seek for a range of security protocols related to different stack layers: introduction of crypto features.
- The fundamental interoperability relies on the compatibility/understandability of the used encryption algorithms, and successful secure keys exchange.



INTEROPERABILITY DEFINITIONS

ETSI Project TIPHON: "Interoperability is the ability of two systems to interoperate using the same communication protocol"

ETSI Technical Committee TISPAN: "Interoperability in Next Generation Networks is the ability of equipment from different manufacturers (or different systems) to communicate together on the same infrastructure (same system), or on another while roaming"

3rd Generation Partnership Project (3GPP1): "Interoperability is the ability of two or more systems or components to exchange data and use information"

Absolute and relative interoperability

- Let S be a set of all the possible features related to analyzed IoT technologies. Let N_S be the cardinal number of the set S. Let technology X(e.g. WiFi) support certain features N_{WiFi}, while some other technology (e.g. ZigBee) provides info on N_{ZB} properties. There is a possibility that different technologies have a subset of identical features.
- The **absolute interoperability** I_A of certain technology is defined as a ratio of a number of features supported by that technology and the total number of features provided by a set of observed technologies, S, and $I_A \in [0,1]$. The WiFi technology has defined I_A as N_{WiFi} / N_S , while for ZigBee I_A is N_{WiFi} / N_S.
- The **relative interoperability** of technology A to the technology B is the ratio of the number of features that are supported by both technologies and the number of properties supported by technology B.

Sustainable interoperabity in IoT

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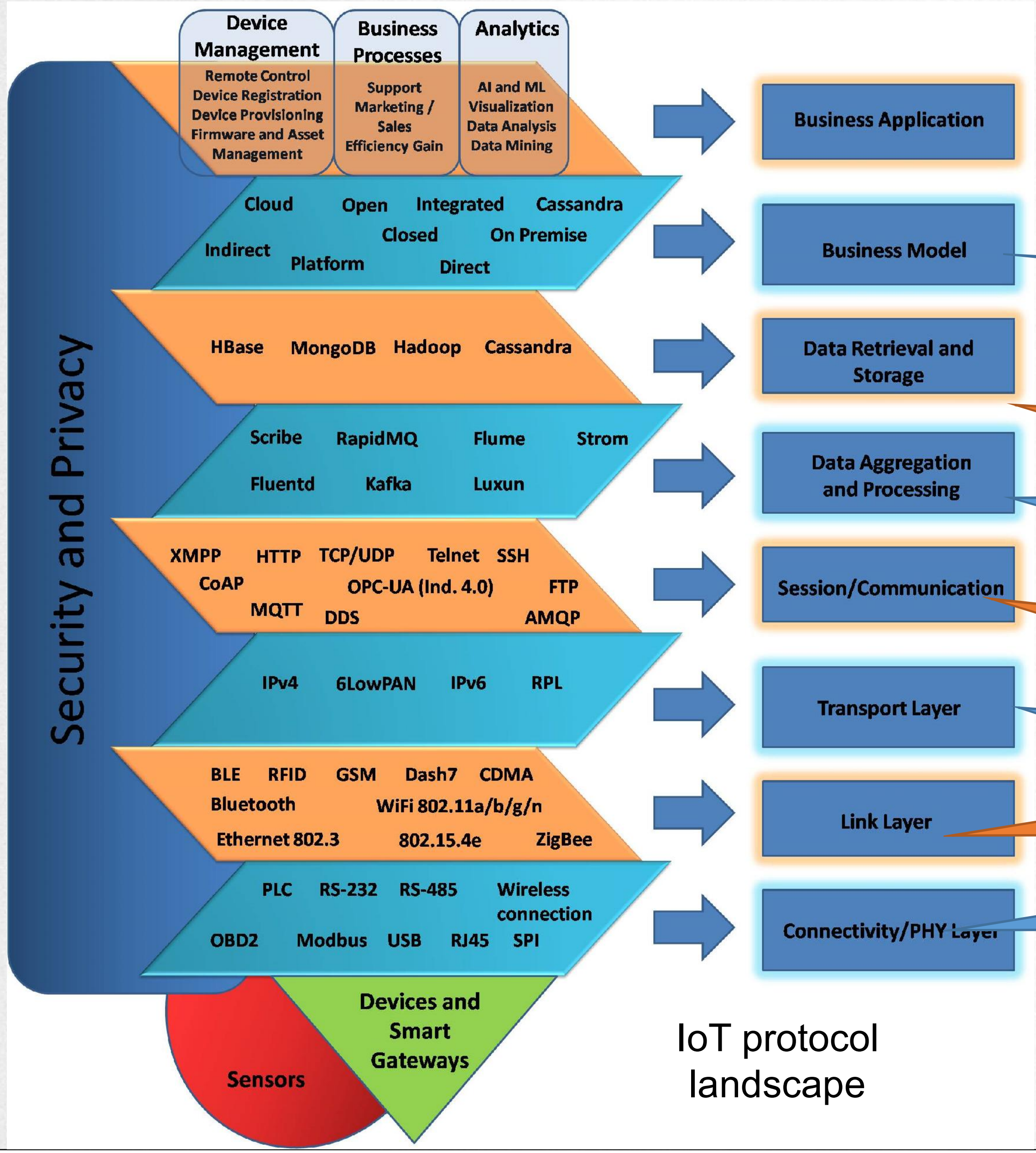
- Sustainability in IoTs based on CC still lacks the integrated proposal
- The existing models mostly direct the attention to one specific sustainability pillar: economy, ecology, social
- General model: **United Nations (UN)** model:
  - 10 principles
  - 17 sustainability development goals for stable sustainability modeling
- **Multi Objective Cloud Computing Sustainability Assessment** model amplifies UN model by **business aspects** that are highly related to the proper application and use of the **IoT** technologies



The IoT protocol landscape is a total mess!

- too many protocols
- wannabe standards
- too many revolutions

→ Need for standardization!

Underlaying business model for the support of business value and processes

The realm of Big Data backend

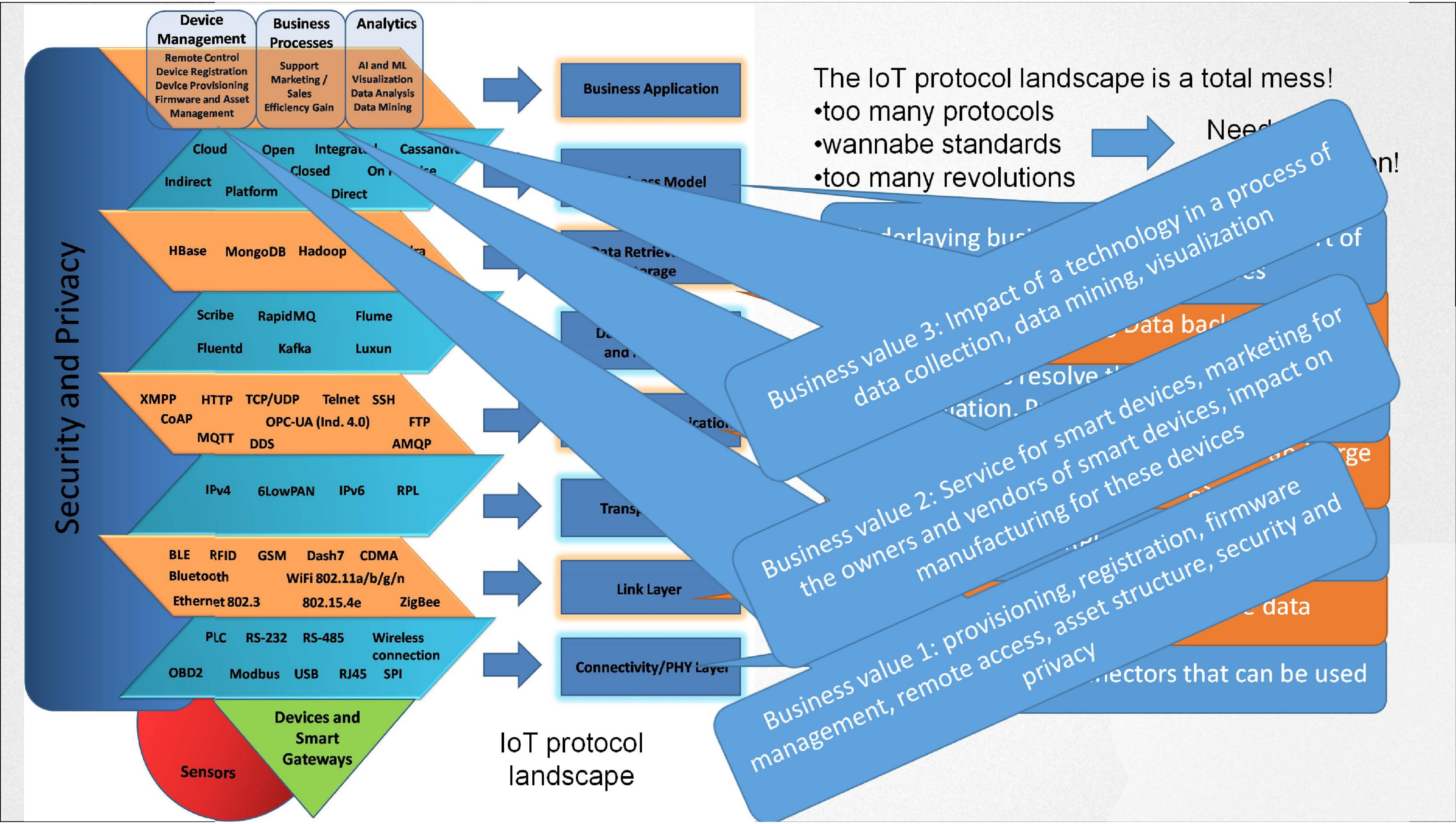
Protocols resolve the collected data manipulation. Processing : real time/ offline

Protocols built for super high volumes and large networks of Things

6LowPAN and RPL are based on IPv6

Technology used for sending the data

A range of physical connectors that can be used



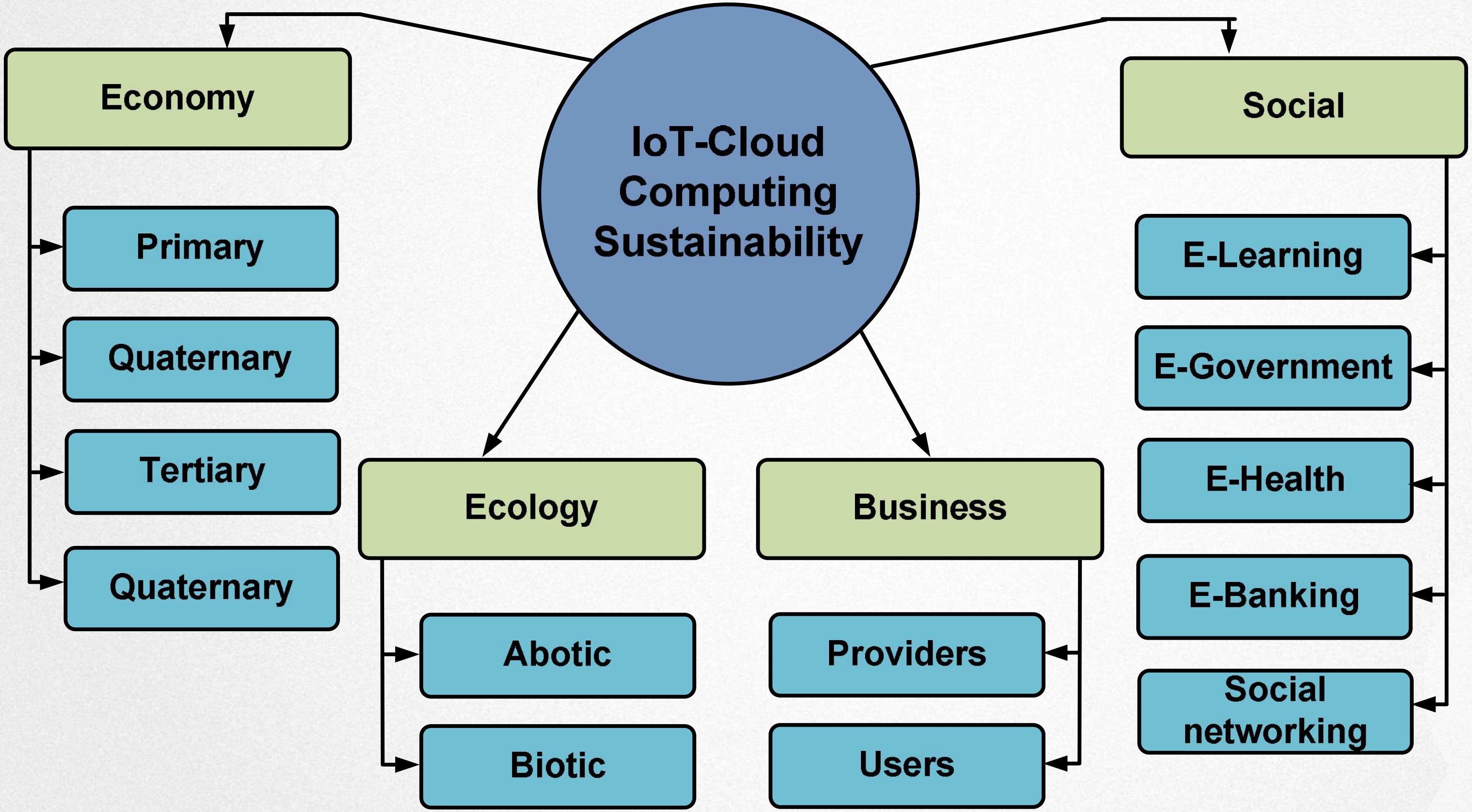
Device Management
Remote Control
Device Registration
Device Provisioning
Firmware and Asset Management
Business Processes
Support
Marketing / Sales
Efficiency Gain
Analytics
AI and ML
Visualization
Data Analysis
Data Mining
Security and Privacy
Cloud
Open
Closed
Indirect
Platform
Direct
HBase
MongoDB
Hadoop
Scribe
RapidMQ
Flume
Fluentd
Kafka
Luxun
XMPP
HTTP
TCP/UDP
Telnet
SSH
CoAP
OPC-UA (Ind. 4.0)
FTP
MQTT
DDS
AMQP
IPv4
6LowPAN
IPv6
RPL
BLE
RFID
GSM
Dash7
CDMA
Bluetooth
WiFi 802.11a/b/g/n
Ethernet 802.3
802.15.4e
ZigBee
PLC
RS-232
RS-485
Wireless connection
OBD2
Modbus
USB
RJ45
SPI
Sensors
Devices and Smart Gateways
Business Application
Link Layer
Connectivity/PHY Layer
IoT protocol landscape
The IoT protocol landscape is a total mess!
•too many protocols
•wannabe standards
•too many revolutions
Business value 3: Impact of a technology in a process of data collection, data mining, visualization
Business value 2: Service for smart devices, marketing for the owners and vendors of smart devices, impact on manufacturing for these devices
Business value 1: provisioning, registration, firmware management, remote access, asset structure, security and privacy

Sustainable interoperability

- A number of social, ecology care, financial, organizational, and legal organizations and government bodies are cooperating in order to define the set of critical points that would tackle common interest and/or information exchange for overall benefit -> **cross-domain interoperability provisioning**

- The final goal is to support the IoT system/network sustainability by responding adequately to the task of building **coherent and interoperable services**, when the individual components and devices are technically different and managed by diverse enterprises, users or organizations.

IoT-Cloud concept of the MO Sustainability Framework



Goal 11: Maximization of secure interoperability

- Security at different TCP/IP protocol stack levels significantly influences the technical interoperability.

Goal 11 = f(Key Management, Encryption/Decryption algorithms, Identity checking mechanisms)

- Security has great impact to the Goal 11, but also to other goals, such as Goal 1 (QoS Maximization). Negative impact is to the performances, while positive impact targets: confidentiality reliability, authentication, integrity, non repudiation.

Security and Cryptography for IoT

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- Cryptosystems are one of the integral parts of security provisioning in nowadays systems. It relies on five-tuple (P, C, K, F, D): set off messages, set of ciphers, set of keys, encryption and decryption function.

$$Tp = T_{\text{Encryption}} + T_{\text{CypherMessage}} + T_{\text{Decryption}}$$

- Encryption/decryption bring delays in processing -> decrease of the system performance.

Goal O_1	QoS maximization	$O_1 = \max QoS(S_i, VM_j) = \max f(QoS\_DesignVariables)$ $QoS(performances) = f(I_{qf}, II_{qf}, S_i \leftrightarrow VM_j, VM_j(S_i \rightarrow S_k))$
Goal O_2	Sensitivity maximization	$O_2 = \max TP_{rate}(TP_{rate\_i})$
Goal O_3	Specificity maximization	$O_3 = \max TN_{rate}(TN_{rate\_i})$
Goal O_4	Resource use efficiency maximization	$O_4 = \max \varphi_1(S_i, VM_j)$ $\varphi_1(S_i, VM_j) = \dfrac{\dfrac{\sum_{j=1}^{N_{VM}} VM_j^{CPU}}{\sum_{i=1}^{N_S} S_i^{CPU}} + \dfrac{\sum_{j=1}^{N_{VM}} VM_j^{RAM}}{\sum_{i=1}^{N_S} S_i^{RAM}} + \dfrac{\sum_{j=1}^{N_{VM}} VM_j^{im}}{\sum_{i=1}^{N_S} S_i^{str}} + \dfrac{\sum_{j=1}^{N_{VM}} VM_j^{bw}}{\sum_{i=1}^{N_S} S_i^{bw}}}{4}$
Goal O_5	Minimization of the number of used virtual machines	$O_5 = \min \varphi_2(VM)$, $\varphi_2(VM) = \sum_{j=1}^{N_{VM}} VM_j(S_i \rightarrow S_k)$
Goal O_6	Minimization of energy consumption	$O_6 = \min P_{CPU}$, $P_{CPU} = \sum_{i=0}^{N_{CPU}-1} \sum_{j=0}^{N_{CPU\_st}-1} \alpha_{i-j}^{CPU} * P_j^{CPU}$ $\alpha_{i-j}^{CPU} = f(Hypervisors_{type}, CPU_{sch}, S_i \leftrightarrow VM_j), VM_j(S_i \rightarrow))$
Goal O_7	Power consumption minimization	$O_7 = \min P_{str}$, $P_{str} = P_{HDD} + P_{SSD}$
Goal O_8	Energy efficiency maximization	$O_8 = \max EE$, $EE = \dfrac{QoS}{P}$
Goal O_9	Maximization of the storage energy efficiency	$O_{8b} = \max EE(str)$, $EE(str) = \dfrac{QoS(str)}{P_{str}}$
Goal O_{10}	Maximization of the networking energy efficiency	$O_{10} = \max EE(networking)$, $EE(networking) = \dfrac{QoS(networking)}{P_{networking}}$

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Set of goals to fullfil IoT business sustainability principles

Goal O_1	QoS maximization	$O_1 = \max QoS(S_i, VM_j) = \max f(QoS\_DesignVariables)$ $QoS(performances) = f(I_{qf}, II_{qf}, S_i \leftrightarrow VM_j, VM_j(S_i \to S_k))$
Goal O_2	Sensitivity maximization	$O_2 = \max TP_{rate}(TP_{rate\_i})$
Goal O_3	Specificity maximization	$O_3 = \max TN_{rate}(TN_{rate\_i})$
Goal O_4	Resource use efficiency maximization	$O_4 = \max \varphi_1(S_i, VM_j)$ $\varphi_1(S_i, VM_j) = \dfrac{\dfrac{\sum_{j=1}^{N_{VM}} VM_j^{CPU}}{\sum_{i=1}^{N_S} S_i^{CPU}} + \dfrac{\sum_{j=1}^{N_{VM}} VM_j^{RAM}}{\sum_{i=1}^{N_S} S_i^{RAM}} + \dfrac{\sum_{j=1}^{N_{VM}} VM_j^{im}}{\sum_{i=1}^{N_S} S_i^{str}} + \dfrac{\sum_{j=1}^{N_{VM}} VM_j^{bw}}{\sum_{i=1}^{N_S} S_i^{bw}}}{4}$
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Goal 11 = f(Key Management, Encryption/Decryption algorithms, Identity checking mechanisms)

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Set of goals to fullfil IoT business sustainability principles

Conclusion

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- IoT is all arround: Smart Cities, Agriculture, Automotive Industry, Health Care, Government, Retail, Asset Traking applications
- **Challenge:** Can IoT flourish under the weight of great expectations?
- Need for fast, secure, low noise, highly energy, storage and CPU efficient, smart technologies -> **interoperable and sustainable**
- Issues: weak environmental characteristics, low compatibility, weak ciphers, delays in encryption/decryption, filesystem authentication incompatibility, traffic analysis algorithms, roaming, etc.

Thank you for your attention

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