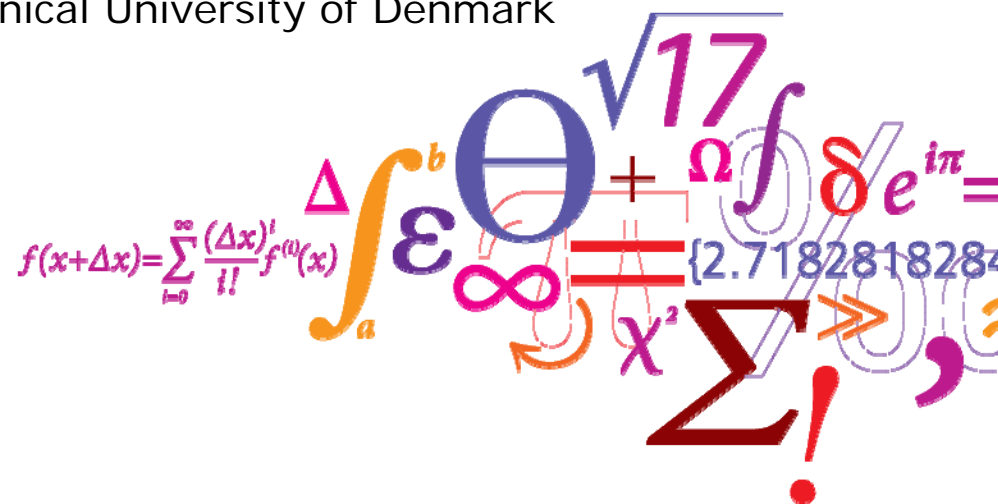


WVITAE Special Session on “Internet of Things (IoT)”

Hyderabad, India, December 2015

Organizers: Knud Erik Skouby & Samant Khajuria, Aalborg University, Denmark,
Birger Andersen (chair, keynote), Technical University of Denmark

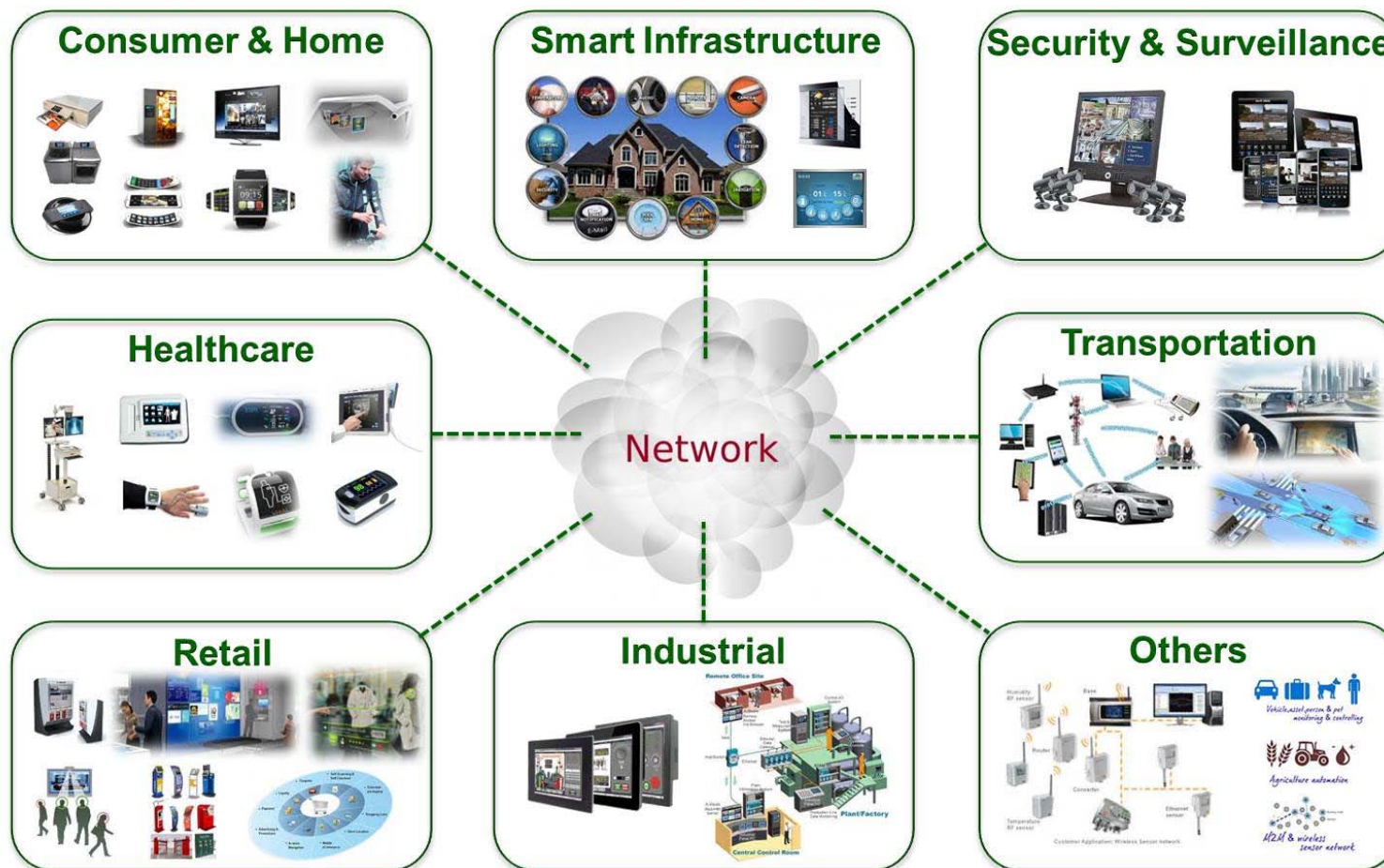


IoT in Theory and Practice

Outline

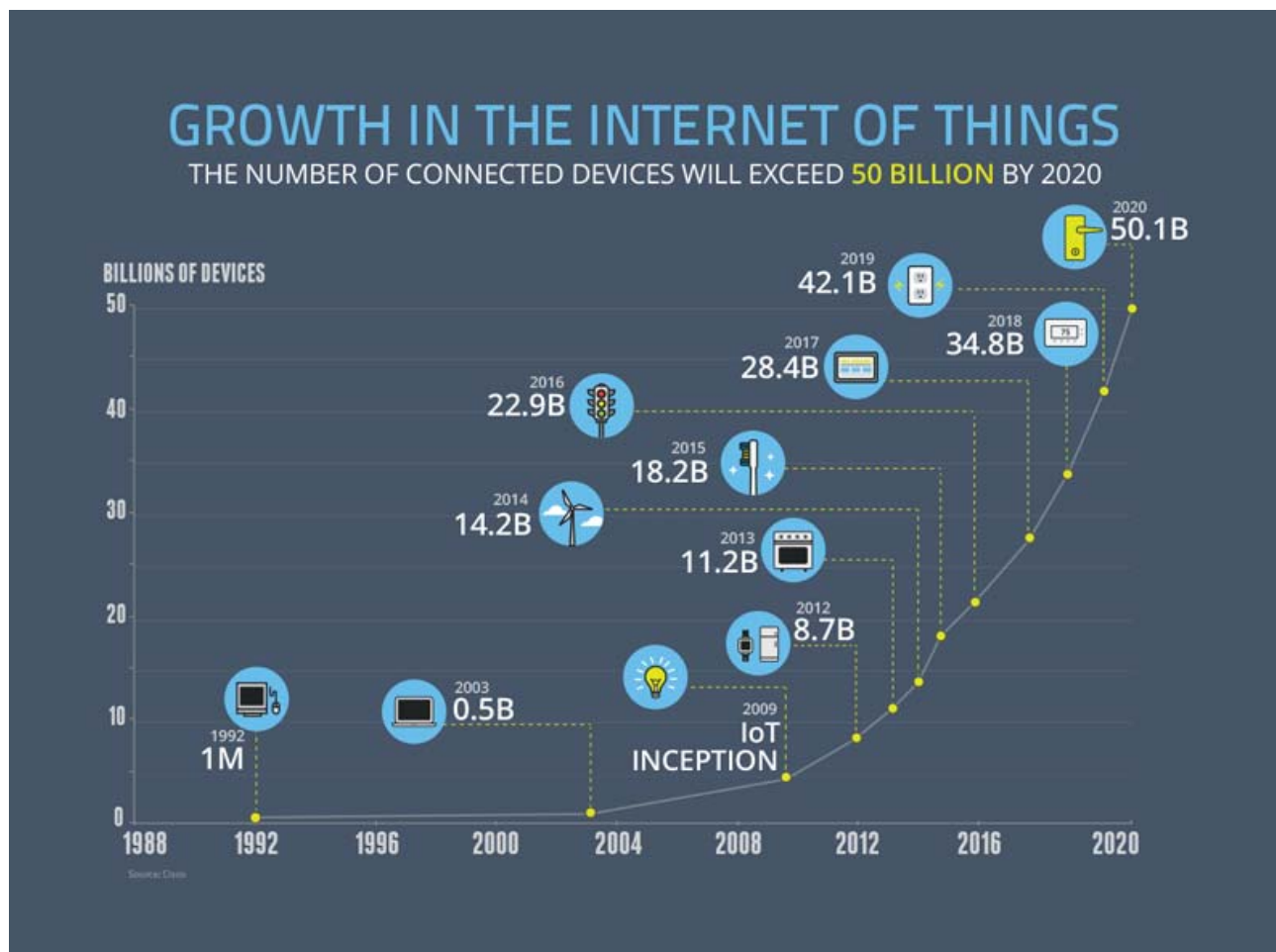
- What IoT can be
- IoT related standards
- Private IoT networks
- IoT gateway approach
- IoT cloud approach
- CLAFIS project
- Summary

What IoT can be



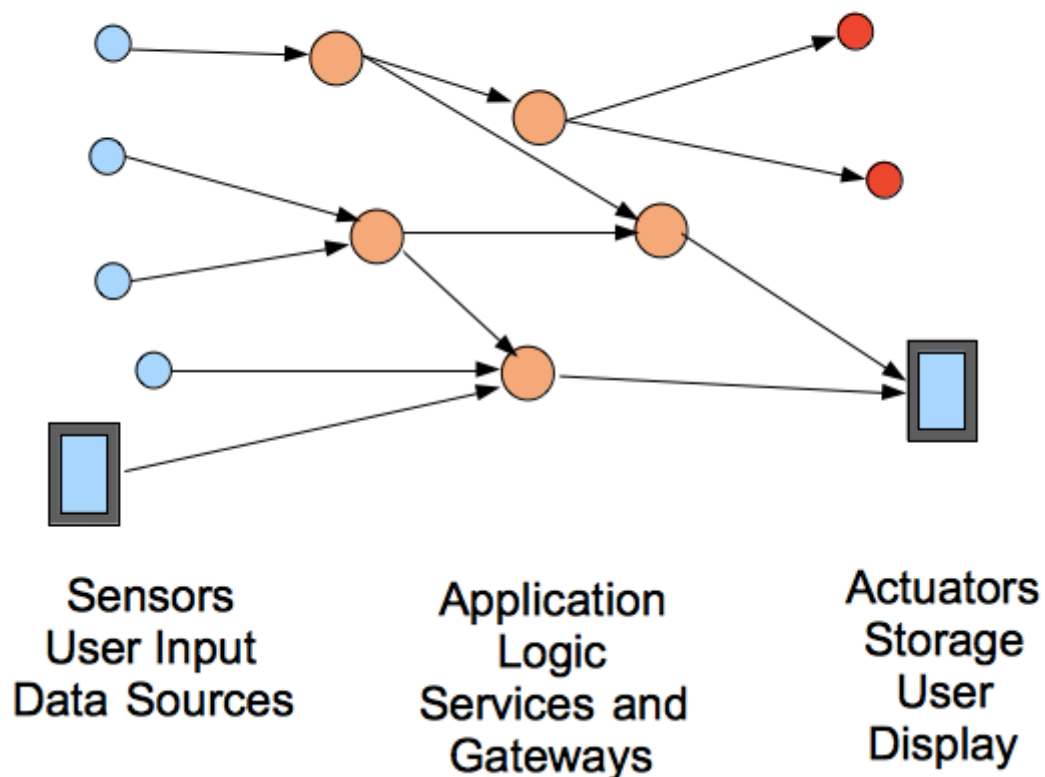
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What IoT can be (2)



What IoT can be (3)

IoT Application is a Graph



This is general view at IoT assuming that devices are simple and non-intelligent with the need for nodes implementing logic and services, etc.

What IoT can be (4)

Research topics related to IoT

- Wireless sensor networks
- Adhoc networking, routing
- Big data, data analytics
- Security, privacy, trust
- Low power consumption
- Energy harvesting
- Mobility and reliability
- Communication standards
- And more...

IoT Related Standards

Partial listing of IEEE standards related to IoT

- [IEEE 754™-2008](#) - IEEE Standard for Floating-Point Arithmetic
- [IEEE 802.1AS™-2011](#) - IEEE Standard for Local and Metropolitan Area Networks - Timing and Synchronization for Time-Sensitive Applications in Bridged Local Area Networks
- [IEEE 802.1Q™-2011](#) - IEEE Standard for Local and metropolitan area networks--Media Access Control (MAC) Bridges and Virtual Bridged Local Area Networks
- [IEEE 802.3™-2012](#) - IEEE Standard for Ethernet
- [IEEE 802.3.1™-2011](#) - IEEE Standard for Management Information Base (MIB) Definitions for Ethernet
- [IEEE 802.11™-2012](#) - IEEE Standard for Information Technology-- Telecommunications and information exchange between systems--Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 10: Mesh Networking

- [IEEE 802.11ad™-2012](#) - IEEE Standard for Local and Metropolitan Area Networks - Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications - Amendment 3: Enhancements for Very High Throughput in the 60 GHz Band
- [IEEE 802.15.1™-2005](#) - IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 15.1: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs)
- [IEEE 802.15.2™-2003](#) - IEEE Recommended Practice for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements Part 15.2: Coexistence of Wireless Personal Area Networks With Other Wireless Devices Operating in Unlicensed Frequency Bands
- [IEEE 802.15.3™-2003](#) - IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements Part 15.3: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs) Amendment 1: Mac Sublayer
- [IEEE 802.15.3c™-2009](#) - IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 15.3: Amendment 2: Millimeter-wave-based Alternative Physical Layer Extension
- [IEEE 802.15.4™-2011](#) - IEEE Standard for Local and metropolitan area networks--Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)
- [IEEE 802.15.4e™-2012](#) - IEEE Standard for Local and metropolitan area networks--Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) Amendment 1: MAC sublayer
- [IEEE 802.15.4™-2012](#) - IEEE Standard for Local and metropolitan area networks-- Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) Amendment 2: Active Radio Frequency Identification (RFID) System Physical Layer (PHY)
- [IEEE 802.15.4g™-2012](#) - IEEE Standard for Local and metropolitan area networks--Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) Amendment 3: Physical Layer (PHY) Specifications for Low-Data-Rate, Wireless, Smart Metering Utility Networks
- [IEEE 802.15.4™-2013](#) - IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs) Amendment: Alternative Physical Layer Extension to support Medical Body Area Network (MBAN) services operating in the 2360-2400 MHz band
- [IEEE 802.15.7™-2009](#) - IEEE Recommended Practice for Information Technology-Telecommunications and Information exchange between systems-Local and metropolitan area networks-Specific requirements Part 15.5: Mesh Topology Capability in Wireless Personal Area Networks (WPANs)
- [IEEE 802.15.6™-2012](#) - IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirements - Part 15.6: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs)used in or around a body
- [IEEE 802.15.7™-2011](#) - IEEE Standard for Local and Metropolitan Area Networks--Part 15.7: Short-Range Wireless Optical Communication Using Visible Light
- [IEEE 802.16™-2012](#) - IEEE Standard for Air Interface for Broadband Wireless Access Systems
- [IEEE 802.16m™-2012](#) - IEEE Standard for Air Interface for Broadband Wireless Access Systems Amendment: Enhancements to Support Machine-to-Machine Applications
- [IEEE 802.16.1b™-2012](#) - IEEE Standard for WirelessMAN-Advanced Air Interface for Broadband Wireless Access Systems - Amendment: Enhancements to Support Machine-to-Machine Applications
- [IEEE 802.22™-2011](#) - IEEE Standard for Information Technology--Telecommunications and Information exchange between systems Wireless Regional Area Networks (WRAN)--Specific requirements Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands
- [IEEE 802.22.1™-2010](#) - IEEE Standard for Information Technology--Telecommunications and Information exchange between systems--Local and metropolitan area networks-- Specific requirements Part 22.1: Standard to Enhance Harmful Interference Protection for Low-Power Licensed Devices Operating in TV Broadcast Bands
- [IEEE 802.22.2™-2012](#) - IEEE Standard for Information Technology--Telecommunications and Information exchange between systems--Local and metropolitan area networks--Specific requirements Part 22.2: Installation and Deployment of IEEE 802.22 Systems
- [IEEE 1284™-2000](#) - IEEE Standard Signaling Method for a Bidirectional Parallel Peripheral Interface for Personal Computers
- [IEEE 1285™-2005](#) - IEEE Standard for Scalable Storage Interface (S/SUP 2/1)
- [IEEE 1301.3™-1992](#) - IEEE Standard for a Metric Equipment Practice for Microcomputers - Convection-Cooled With 2.5mm Connectors
- [IEEE 1377™-2012](#) - IEEE Standard for Utility Industry Metering Communication Protocol Application Layer (End Device Data Tables)
- [IEEE 1394™-2008](#) - IEEE Standard for a High-Performance Serial Bus
- [IEEE 1451.0™-2007](#) - IEEE Standard for a Smart Transducer Interface for Sensors and Actuators - Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats
- [IEEE 1547™-2003](#) - IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
- [IEEE 1547.1™-2005](#) - IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems
- [IEEE 1547.2™-2008](#) - IEEE Application Guide for IEEE Std 1547™, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems
- [IEEE 1547.3™-2007](#) - IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems
- [IEEE 1547.4™-2011](#) - IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems
- [IEEE 1547.6™-2011](#) - IEEE Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks
- [IEEE 1609.2™-2012](#) - IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages
- [IEEE 1609.3™-2010](#) - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services
- [IEEE 1609.4™-2010](#) - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-channel Operation
- [IEEE 1609.11™-2010](#) - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)-- Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS)
- [IEEE 1609.12™-2012](#) - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations
- [IEEE 1675™-2008](#) - IEEE Standard for Broadband Over Powerline Hardware 1900.1-2008 IEEE Standard Definitions and Concepts for Dynamic Spectrum Access: Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management
- [IEEE 1701™-2011](#) - IEEE Standard for Optical Port Communication Protocol to Complement the Utility Industry End Device Data Tables
- [IEEE 1702™-2011](#) - IEEE Standard for Telephone Modem Communication Protocol to Complement the Utility Industry End Device Data Tables
- [IEEE 1703™-2012](#) - IEEE Standard for Local Area Network/Wide Area Network (LAN/WAN) Node Communication Protocol to complement the Utility Industry End Device Data Tables
- [IEEE 1775™-2010](#) - IEEE Standard for Power Line Communication Equipment--Electromagnetic Compatibility (EMC) Requirements--Testing and Measurement Methods
- [IEEE 1815™-2012](#) - IEEE Standard for Electric Power Systems Communications - Distributed Network Protocol (DNP3) 2200-2012 IEEE Standard Protocol for Stream Management in Media Client Devices
- [IEEE 1888™-2011](#) - IEEE Standard for Ubiquitous Green Community Control Network Protocol
- [IEEE 1900.1™-2008](#) - IEEE Standard Definitions and Concepts for Dynamic Spectrum Access: Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management
- [IEEE 1900.2™-2008](#) - IEEE Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence Between Radio Systems
- [IEEE 1900.4™-2009](#) - IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks
- [IEEE 1900.4a™-2011](#) - IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks Amendment 1: Architecture and Interfaces for Dynamic Spectrum Access Networks in White Space Frequency Bands
- [IEEE 1901™-2010](#) - IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications
- [IEEE 1902.1™-2009](#) - IEEE Standard for Long Wavelength Wireless Network Protocol
- [IEEE 1906.1™-2012](#) - IEEE Draft Standard for a Convergent Digital Home Network for Heterogeneous Technologies
- [IEEE 2200™-2012](#) - IEEE Standard Protocol for Stream Management in Media Client Devices
- [IEEE 2030™-2011](#) - IEEE Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), End-Use Applications, and Loads
- [IEEE 11073-00101™-2008](#) - IEEE Standard for Health Informatics - PoC Medical Device Communication - Part 00101: Guide--Guidelines for the Use of RF Wireless Technology
- [IEEE 11073-10102™-2012](#) - IEEE Standard for Health Informatics - Point-of-care medical device communication - Nomenclature - Annotated ECG
- [IEEE 11073-10103™-2012](#) - IEEE Standard for Health Informatics - Point-of-care medical device communication - Nomenclature - Implantable device, cardiac
- [IEEE 11073-10201™-2004](#) - IEEE Standard for Health Informatics - Point-Of-Care Medical Device Communication - Part 10201: Domain Information Model
- [IEEE 11073-10404™-2010](#) - IEEE Standard for Health Informatics-Personal health device communication Part 10404: Device specialization-Pulse oximeter
- [IEEE 11073-10406™-2011](#) - IEEE Standard for Health Informatics--Personal health device communication Part 10406: Device specialization-- Basic electrocardiograph (ECG) (1- to 3-lead ECG)
- [IEEE 11073-10407™-2010](#) - IEEE Standard for Health Informatics Personal health device communication Part 10407: Device specialization Blood pressure monitor
- [IEEE 11073-10408™-2010](#) - IEEE Standard for Health Informatics Personal health device communication Part 10408: Device specialization Thermometer
- [IEEE 11073-10415™-2010](#) - IEEE Standard for Health Informatics Personal health device communication Part 10415: Device specialization Weighing scale 11073-10420-2010 IEEE Standard for Health Informatics -- Personal health device communication Part 10420: Device specialization -- Body composition analyzer
- [IEEE 11073-10417™-2011](#) - IEEE Standard for Health Informatics Personal health device communication Part 10417: Device specialization Glucose meter
- [IEEE 11073-10418™-2011](#) - IEEE Standard for Health Informatics - Personal health device communication - Device specialization - International normalized ratio (INR) monitor
- [IEEE 11073-10420™-2010](#) - IEEE Standard for Health Informatics -- Personal health device communication Part 10420: Device specialization -- Body composition analyzer
- [IEEE 11073-10441™-2008](#) - IEEE Standard for Health Informatics - Personal Health Device Communication - Part 10441: Device Specialization - Cardiovascular Fitness and Activity Monitor
- [IEEE 11073-30300™-2004](#) - IEEE Standard for Health Informatics - Point-of-care medical device communication - Transport profile - Infrared
- [IEEE 11073-30400™-2010](#) - IEEE Standard for Health Informatics --Point-of-care medical device communication Part 30400: Interface profile--Cabled Ethernet
- [IEEE 14575™-2000](#) - IEEE Standard for Heterogeneous Interconnect (HIC) (Low-Cost, Low-Latency Scalable Serial Interconnect for Parallel System Construction)
- [IEEE 21450™-2010](#) - IEEE Standard for Information technology -- Smart transducer interface for sensors and actuators -- Common functions, communication protocols, and Transducer Electronic Data Sheet (TEDS) formats
- [IEEE 21451.1™-2010](#) - IEEE Standard for Information technology -- Smart transducer interface for sensors and actuators -- Part 1: Network Capable Application Processor (NCAP) information model
- [IEEE 21451.2™-2010](#) - IEEE Standard for Information technology -- Smart transducer interface for sensors and actuators -- Part 2: Transducer to microprocessor communication protocols and Transducer Electronic Data Sheet (TEDS) formats
- [IEEE 21451.4™-2010](#) - IEEE Standard for Information technology -- Smart transducer interface for sensors and actuators -- Part 4: Mixed-mode communication protocols and Transducer Electronic Data Sheet (TEDS) formats
- [IEEE 21451.7™-2011](#) - IEEE Standard for Smart Transducer Interface for Sensors and Actuators--Transducers to Radio Frequency Identification (RFID) Systems Communication Protocols and Transducer Electronic Data Sheet Formats

And ~30 IEEE standards being drafted

Plus IETF, 3GPP, ITU, ...

Private IoT Networks

- Many services not for the public at all
- Authorization
 - Everyone not access/control health IoT, home automation IoT, etc.
 - Need for login procedure, assign priviledges, etc.
- Privacy/confidentiality
 - Private data should be kept private (health data, etc.)
 - Need for encryption and key handling
- Authencity
 - Data and commands should be original (as coming from right source)
 - Need to authenticate communication, MACs, etc.
- Integrity
 - Data and commands should not change (by a 3rd party)
 - Need for cryptograhpic integrity checks

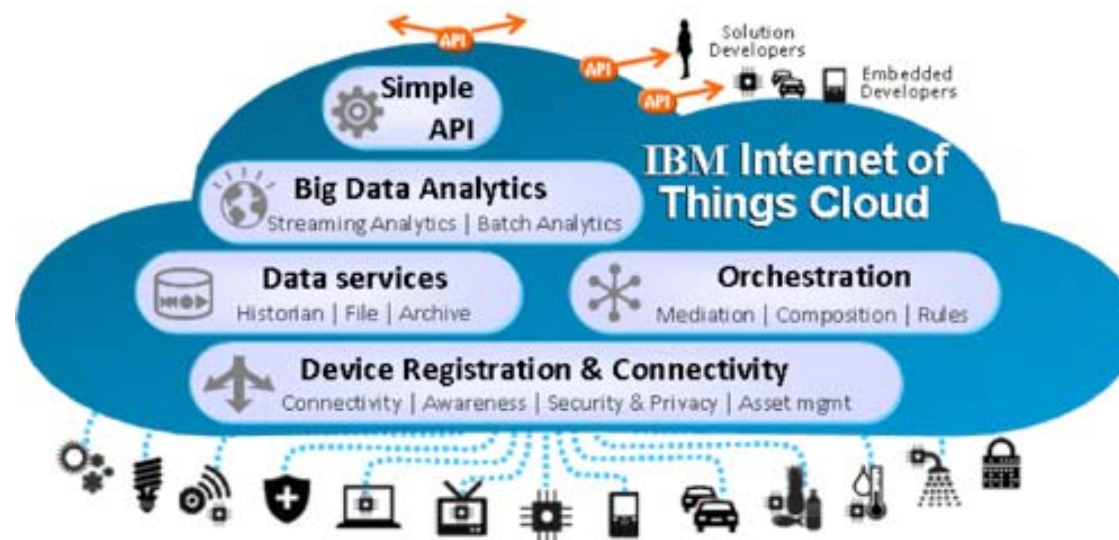
IoT Gateway Approach

- Implement domain specific standards for the things in a cluster, Zigbee, Z-wave, etc.
- Implement a few Internet standards to get things online, TCP/IP, HTTP, REST, WS, ...
- Implement private IoT network, IPSec or HTTPS, etc.
- In general bridging heterogenous communication protocols
- In general harmonising incompatible devices and frameworks
- Ad-hoc discovery of devices
- Representation of physical world objects
- Mapping software IoT resources to physical world objects
- Mapping business domain entities to IoT resources
- Typical REST- and WS-based service interfaces



IoT Cloud Approach

- Data aggregation and orchestration (from multiple devices, gateways)
- Data services, archive historical data
- Big data analytics, data fusion, prediction, recommendation, control/automation
- User application APIs (HTTP, REST, WS)
- Device registration, connectivity, security, privacy, reliability, scalability



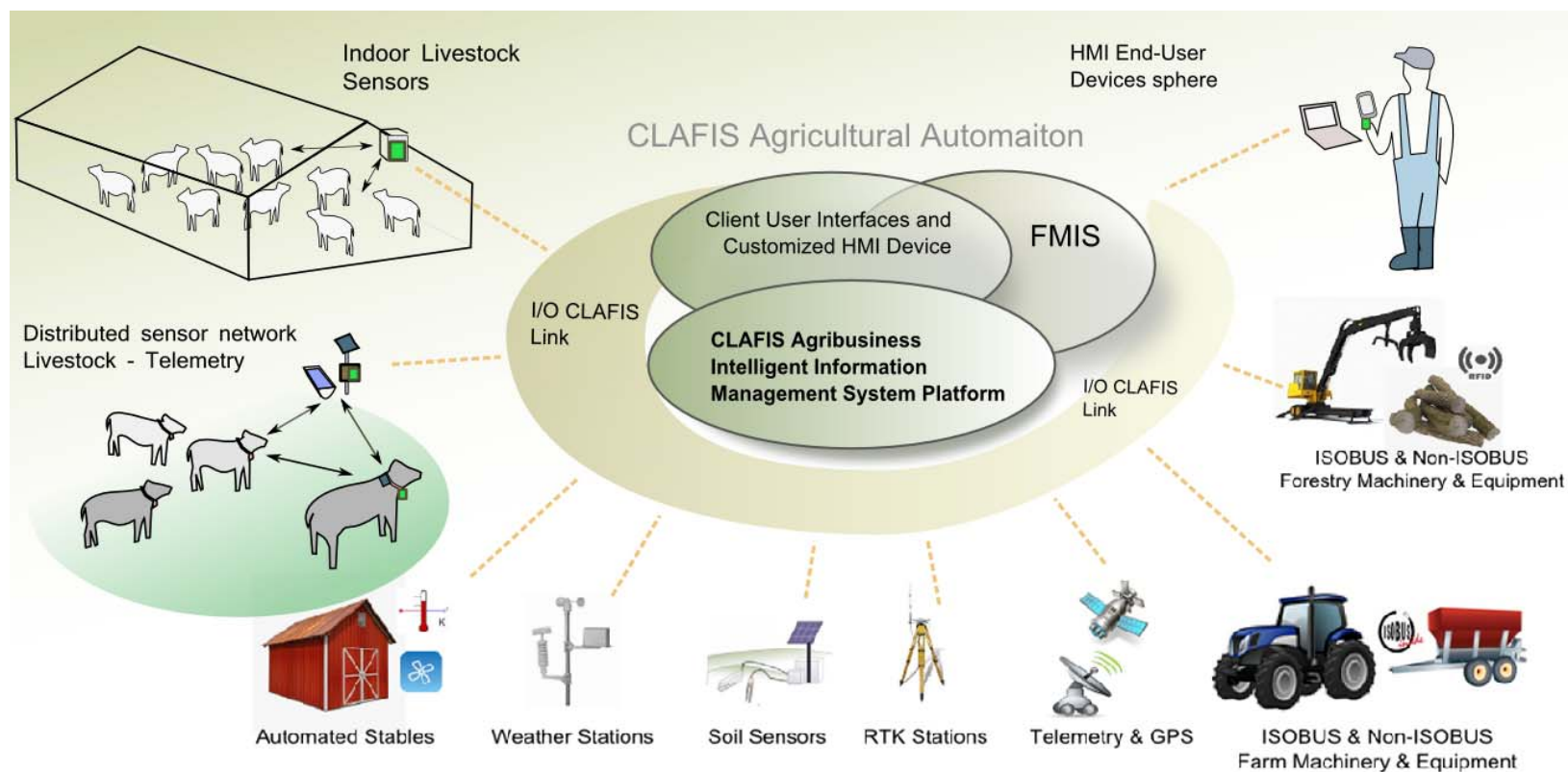
The IBM view

CLAFIS Project

- CLAFIS = Crop, Livestock and Forest Integrated system
- Data aggregation and automation
- EU FP7 collaboration project
- Budget ~5 mill. Euro
- Duration 36 months, ending October 2016
- 13 partners
- Prof. Birger Andersen (DTU) coordinator
- Website <http://www.clafis-project.eu>



CLAFIS Project (2)



<http://www.clafis-project.eu>

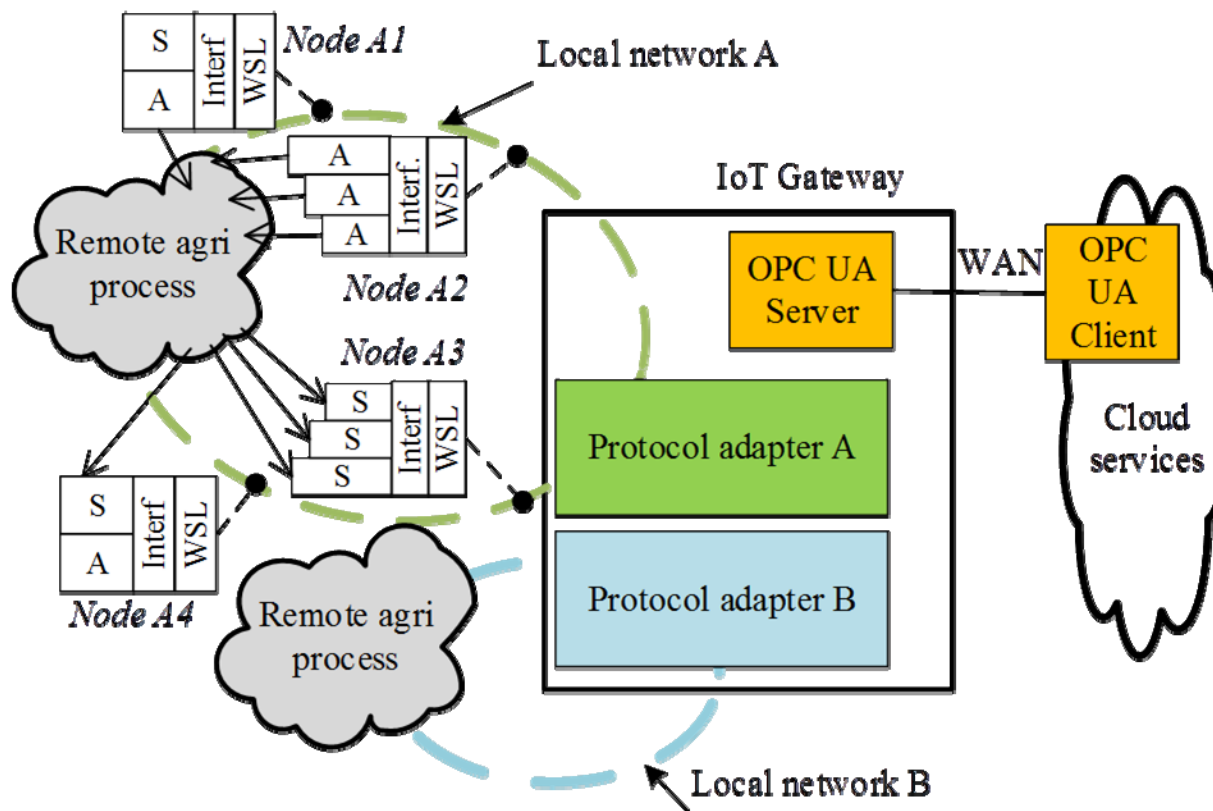
CLAFIS Project (3)

Benefits of the CLAFIS technology to the various supply chains include

- Interoperability, connectivity and coherence amongst agriculture systems, equipment and processes
- Effective use and access of agricultural data resources by farmers and end-users through advanced HMI and knowledge management
- Apply standardized data formats
- Standards for 3rd party developers for innovative agricultural products and services
- Access to agricultural knowledge across national borders
- European-wide professional networking, for sharing experiences and best practices
- Improved real-time and onsite guidance and automatic tracking of processes and activities
- Security, privacy, reliability, data safety backup

CLAFIS Project (4)

Solution architecture based on gateway, cloud, OPC UA (by OPC Foundation) being primary protocol standard gateway to cloud



CLAFIS Project (5)

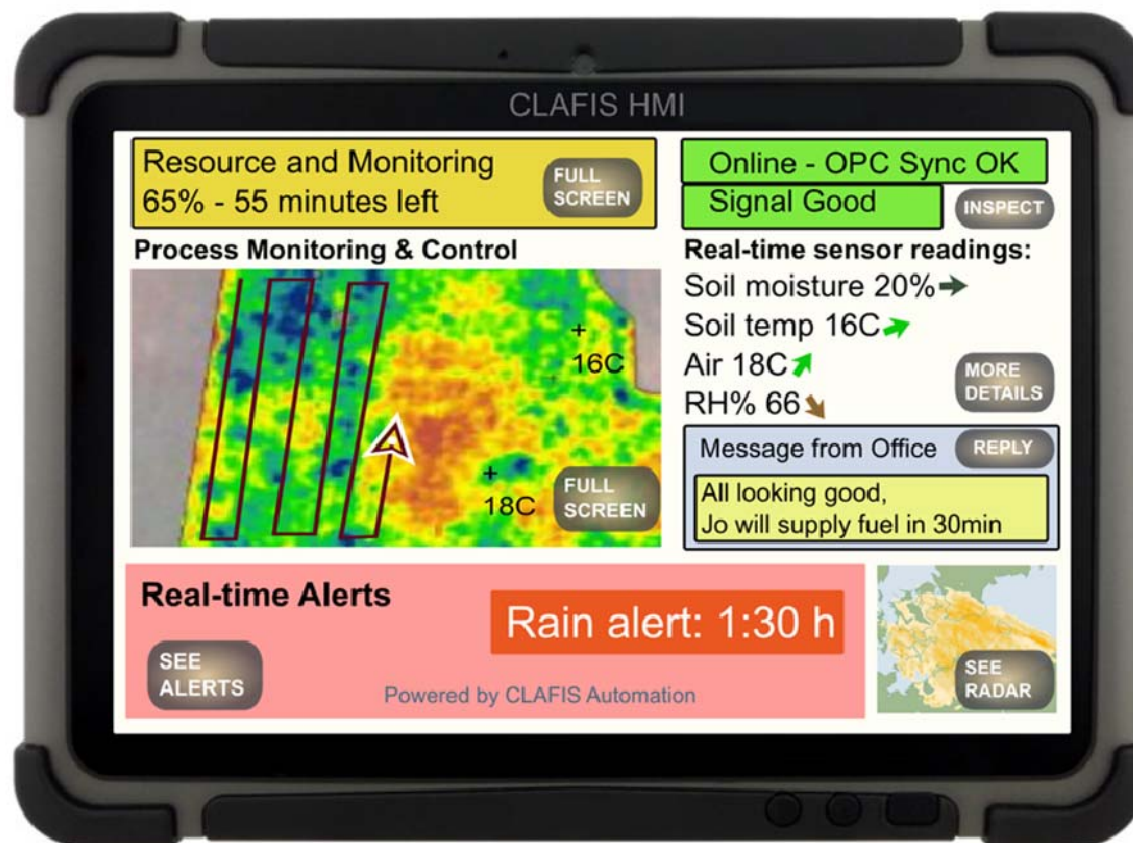
Gateway features

- IoT device side connections and protocols
 - CAN bus, Modbus, RS232
 - 8 digital i/o, 8 analog i/o
 - 169 MHz wireless modem
- IoT cloud side connections and protocols
 - 2G/3G/4G modem
 - Ethernet, WiFi dual band
 - TCP/IP v4/v6, OpenVPN client
 - OPC UA server
- Sensors (for mobile use)
 - Accelerometer, gyroscope, GPS receiver
- Processing
 - ARM Cortex A8 CPU
 - Management services (key installation, etc.)
 - Data buffering, data validation
 - Protocol adapters



CLAFIS Project (6)

HMI example (e.g. device located in tractor)



Summary

My personal view

- IoT covers a large variety of possibilities and research topics
- Too many standards involved
- Tendency that IoT will be in private networks
- Tendency to use gateways (security, privacy, bridging)
- Tendency to use clouds (data services, storage, analytics, etc.)
- Believe just a small part of 50 billion devices by 2020 will be publicly available on the Internet

Questions?