# *Internet Of Thing Infrastructure*


**Dr. –Ing. Somrak Petchartee**

**Thailand IoT Consortium**

**Research Operation Manager**
**Brownien Lab**
**R&D Department**
**CAT Telecom PCL**

www.brownien_lab.cattelecom.com

# Biography

**Education:**

**Federal Armed Forces University (UniBW), Faculty of Aerospace Engineering, Munich, Germany**
- **Dr. -Ing., Doctoral degrees in engineering**
- **Research Topic: Object Manipulation and Force Control by Using Tactile Sensors**
- **Scholarship Donor: Research Assistant**

**Asian Institute of Technology (AIT), Thailand**
- **M. Eng., Computer Engineering**
- **Thesis Topic: Cooperation of Multiple Robot Arms By Kinematic-Coordinate Transformation Distribution**
- **Scholarship Donor: Royal Thai Government (RTG)**

**King Mongkut's Institute Of Techonology Ladkrabang (KMITL), Thailand**
- **B.Eng., Telecommunication Engineering**
- **Thesis Topic: G3 Facsimile Protocol Analyzer**
- **1st Class Honors, Class Rank 1**
- **Scholarship Donor: first position in entrance exam.**

**Work Experiences:**

- **Intelligent Robot Laboratory, Faculty of Aerospace Engineering, University of Federal Armed Forces, Germany;**
- **Siemens Automotive Company, Germany; solutions and services for automotive production**
- **Dallmeier Electronic Company, Germany; image processing and recording, the CCTV monitoring field, image transmission**
- **Brownien Lab, R&D Department, CAT Telecom PCL, Thailand**

**Research Interests**

- Machine Vision
- SDR , FPGA , Wireless Sensor
- Fiber Optic , Optical Path Design
- Robotic and Automation

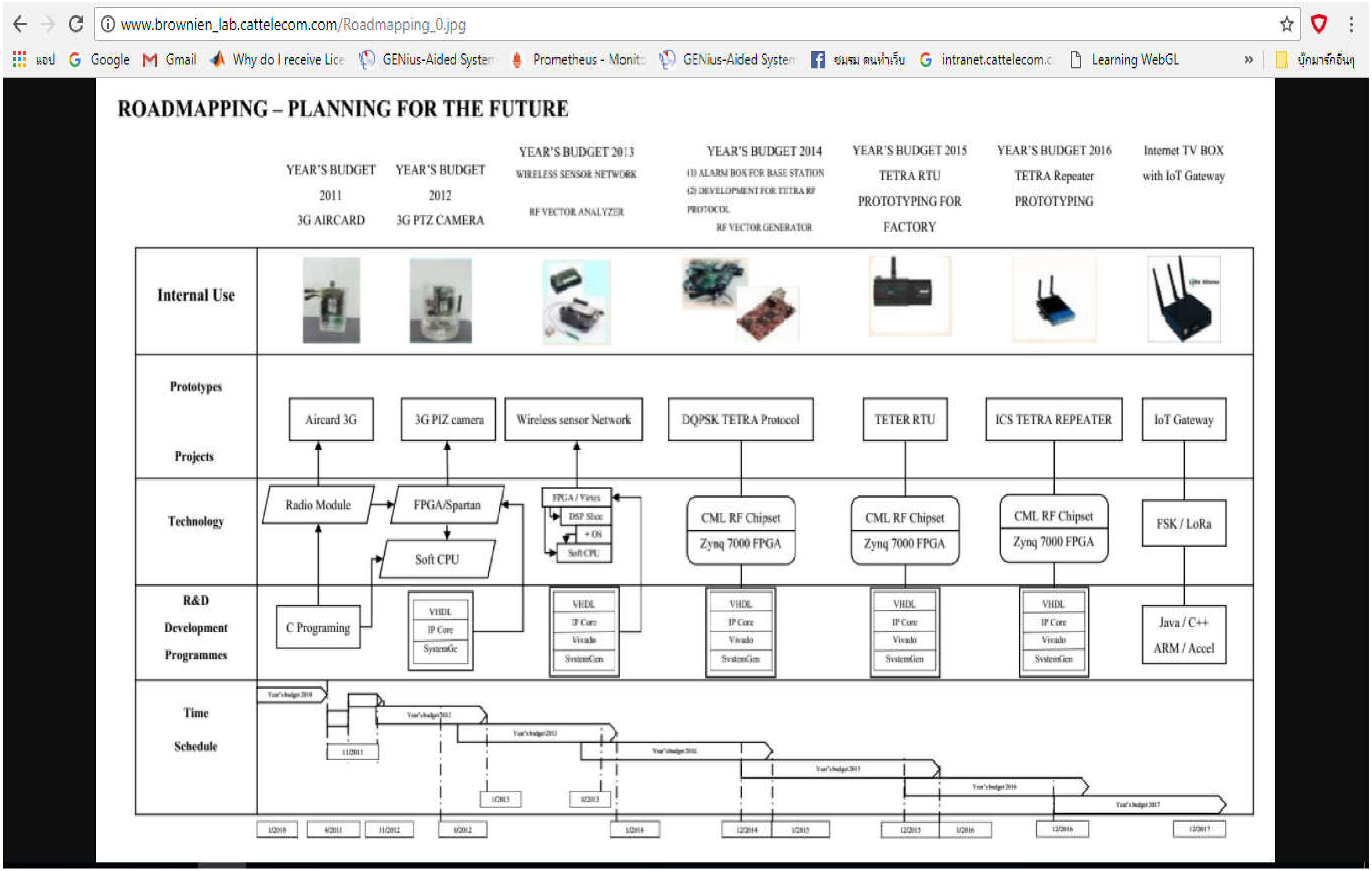
**Award and Honors**

- Highly Commended Award Winner, Industrial Robotic Journal, Vol.35 No.4, 2008. Emerald Group Publishing Limited , England.
- Award SEPO Thailand: Outstanding Innovation Award (2016).
- **22** papers in the international conferences, 10 journal articles, 1 book

❑Joint Management Committee of Engineering Institute of Thailand
❑Adjunct Faculty of Asian Institute Of Technology (AIT), School Of Engineering and Technology.
❑The luminaries funding committee: Office for Educational Technology Development Fund. The Permanent Secretary, Ministry of Education

# Brownien Laboratory

## Research and Development Department
## CAT Telecom PCL



www.brownien_lab.cattelecom.com/Roadmapping_0.jpg
ROADMAPPING – PLANNING FOR THE FUTURE
YEAR'S BUDGET 2011 3G AIRCARD
YEAR'S BUDGET 2012 3G PTZ CAMERA
YEAR'S BUDGET 2013 WIRELESS SENSOR NETWORK RF VECTOR ANALYZER
YEAR'S BUDGET 2014 (1) ALARM BOX FOR BASE STATION (2) DEVELOPMENT FOR TETRA RF PROTOCOL RF VECTOR GENERATOR
YEAR'S BUDGET 2015 TETRA RTU PROTOTYPING FOR FACTORY
YEAR'S BUDGET 2016 TETRA Repeater PROTOTYPING
Internet TV BOX with IoT Gateway
Internal Use
Prototypes
Projects
Aircard 3G
3G PIZ camera
Wireless sensor Network
DQPSK TETRA Protocol
TETER RTU
ICS TETRA REPEATER
IoT Gateway
Technology
Radio Module
FPGA/Spartan
Soft CPU
FPGA / Virtex
DSP Slice
+ OS
Soft CPU
CML RF Chipset
Zynq 7000 FPGA
FSK / LoRa
R&D Development Programmes
C Programing
VHDL
IP Core
SystemGe
Vivado
SystemGen
Java / C++
ARM / Accel
Time Schedule
11/2011
1/2013
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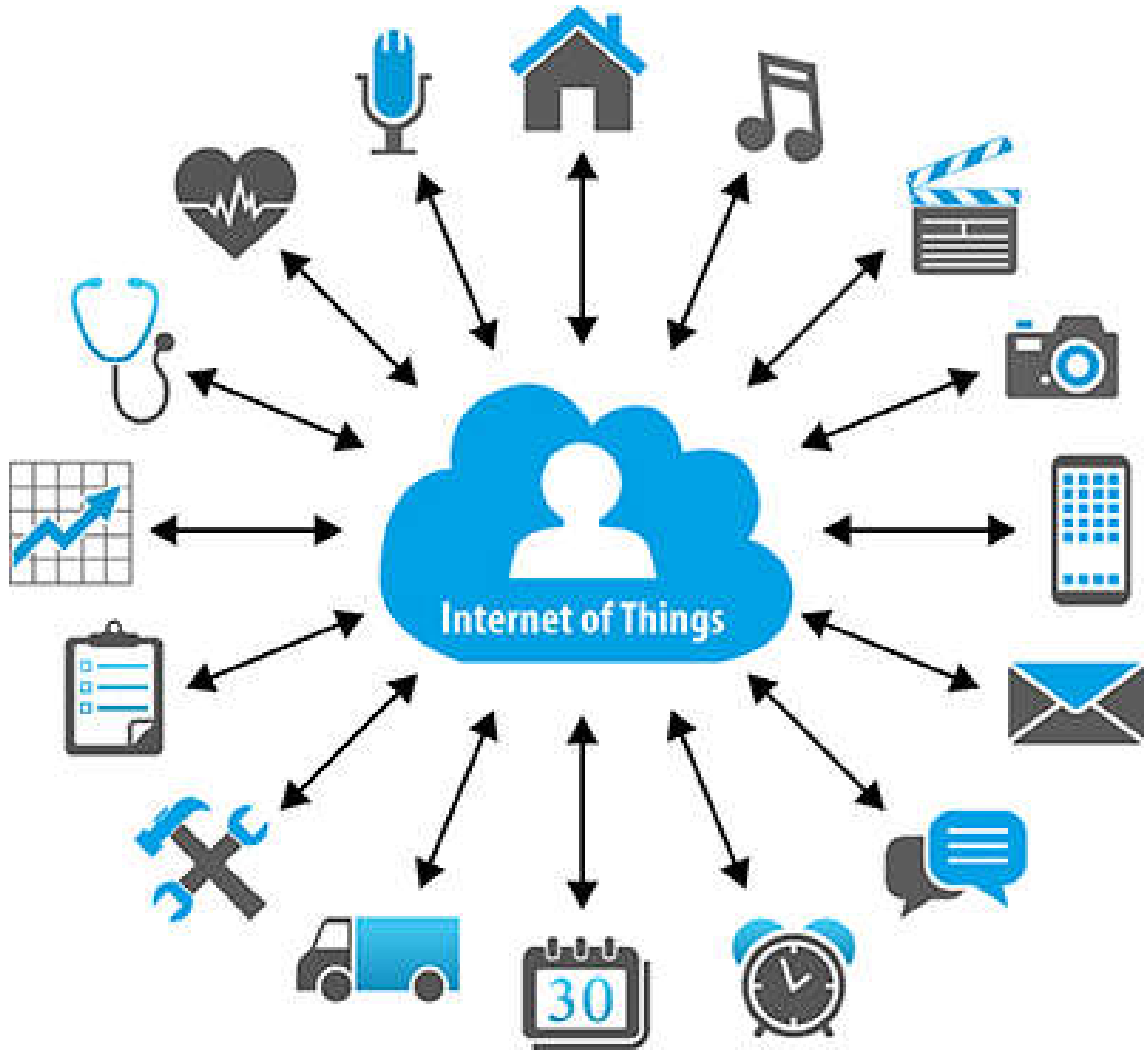
1/2016
12/2016
12/2017


Internet of Things
30

1 Gartner has forecast that most technology components such as radio, WiFi, sensors and global positioning systems (GPS), could see a drop in cost of 15% to 45% from 2010 to 2015 To illustrate, with cheaper temperature sensors, cold chain retailers would consider deploying more temperature sensors to monitor their perishable produce as it traverses the supply chain.

| Technology Component | 2010 Cost* | 2015 Cost** |
|---|---|---|
| Radio, Wi-Fi | 1.50 | 0.80 |
| Radio, Bluetooth | 1.00 | 0.50 |
| Processor (basic 8-bit microcontroller chip with embedded flash memory) | 1.00 | 0.85 |
| Sensor (temperature) | 1.00 | 0.75 |
| Sensor (vibration/accelerometer) | 1.50 | 1.00 |
| Camera (1.8 megapixel CMOS image sensor) | 1.80 | 1.20 |
| Microphone | 1.20 | 1.00 |
| GPS | 1.25 | 0.70 |
| Energy Source (inductive loop wireless power, incremental cost per unit) | 2.50 | 2.00 |

*Lowest costs for simplest realistic implementation; **2015 cost assumes the same functionality as the corresponding 2010 figure
CMOS = complementary metal-oxide semiconductor

Source: Gartner (November 2011)

<u>Falling cost of technology components</u> Gartner 2009

2

# Top 10 algorithms in data mining

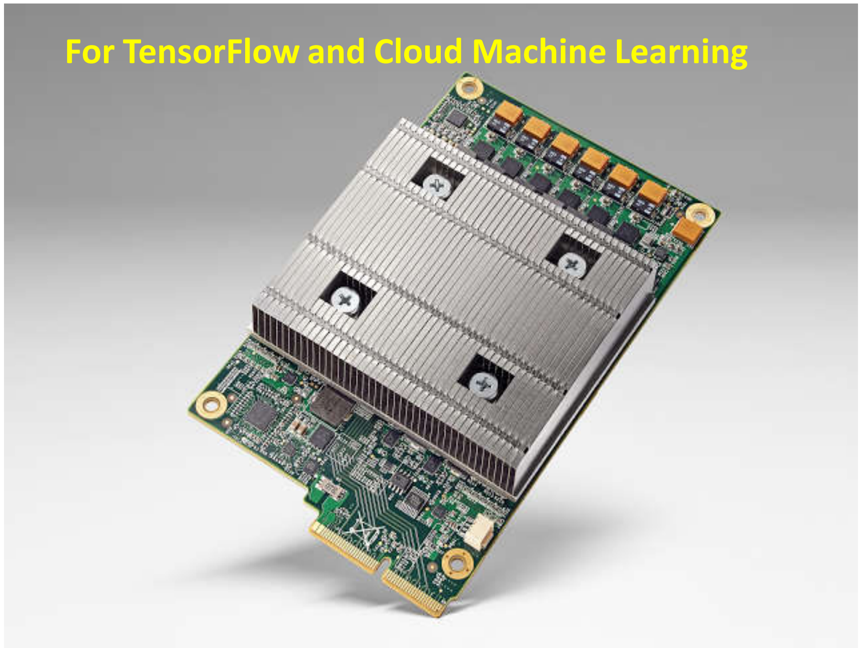
The 10 algorithms identified by the IEEE International Conference on Data Mining (ICDM)

DESCRIPTION OF THE 10 CLASSIFIERS CANDIDATES

| METHODS | DESCRIPTION | REF |
|---|---|---|
| AdaBoost | Adaptive Boosting Negative Correlation Learning Extension with C4.5 Decision Tree as Base Classifier. | [10] |
| Apriori | Association rule mining using the Apriori algorithm. | [11] |
| Bagging | Multi-classifier learning approach with C4.5 as baseline algorithm. | [12], [13] |
| C4.5 | Generate classifier expressed as decision trees | [14] |
| CART | Classification and Regression Tree. | [15] |
| EM | Expectation-Maximization algorithm | [16] |
| K-means | K means Classifier. | [17] |
| KNN | K-Nearest Neighbors Classifier. | [18] |
| NB | Nave-Bayes. | [19], [20] |
| SVM | Support vector networks. | [21] |

2017 (11/18-11/21) New Orleans, LA, USA

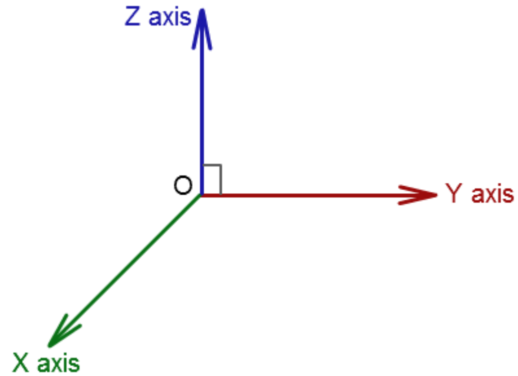
# 3 Google supercharges machine learning tasks with TPU custom chip



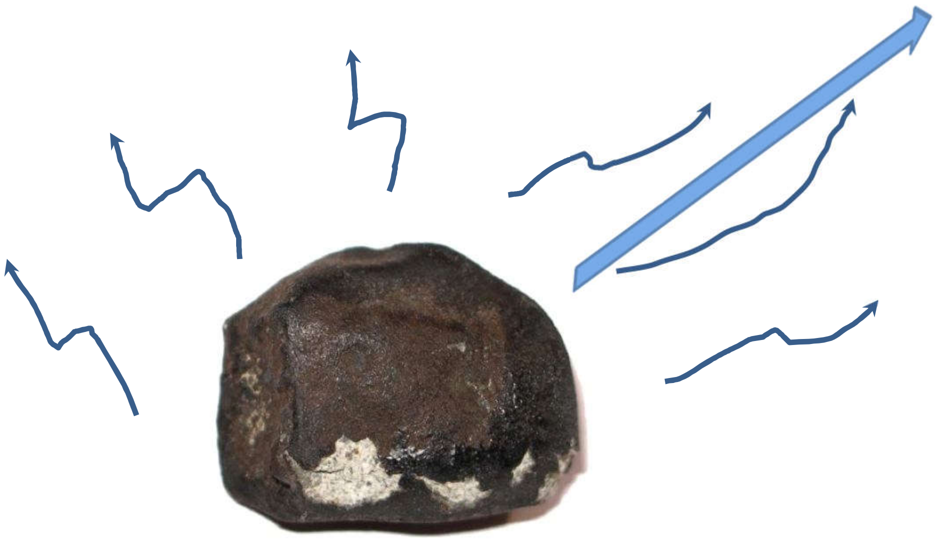

Tensor Processing Unit board (TPU)

- Street View,
- Maps and navigation
- AlphaGo
- Inbox Smart Reply,
- Voice search

**TPU is tailored to machine learning applications, allowing the chip to be more tolerant of reduced computational precision, which means it requires fewer transistors per operation. Because of this, we can squeeze more operations per second into the silicon, use more sophisticated and powerful machine learning models and apply these models more quickly, so users get more intelligent results more rapidly. A board with a TPU fits into a hard disk drive slot in our data center racks.**



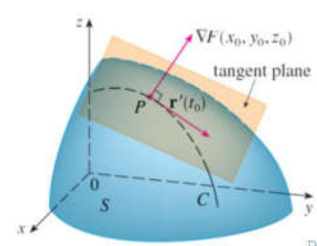

Temperature = $f(x, y, z) = 100 - 2x^2 + y^2 - z^2$



$$\nabla f = \left[ i\frac{\partial}{\partial x} + j\frac{\partial}{\partial y} + k\frac{\partial}{\partial z} \right] f$$

$\nabla$ is commonly called "del" and the gradient "del f"

- The equation $\nabla F(x_0, y_0, z_0) \cdot \mathbf{r}'(t_0)$ says that the gradient vector at $P$, $\nabla F(x_0, y_0, z_0)$, is perpendicular to the tangent vector $\mathbf{r}'(t_0)$ to any curve $C$ on $S$ that passes through $P$.



# Hardware Play a Major Role:

Hardware components play an important role in processing life cycle in terms of speed and performance.

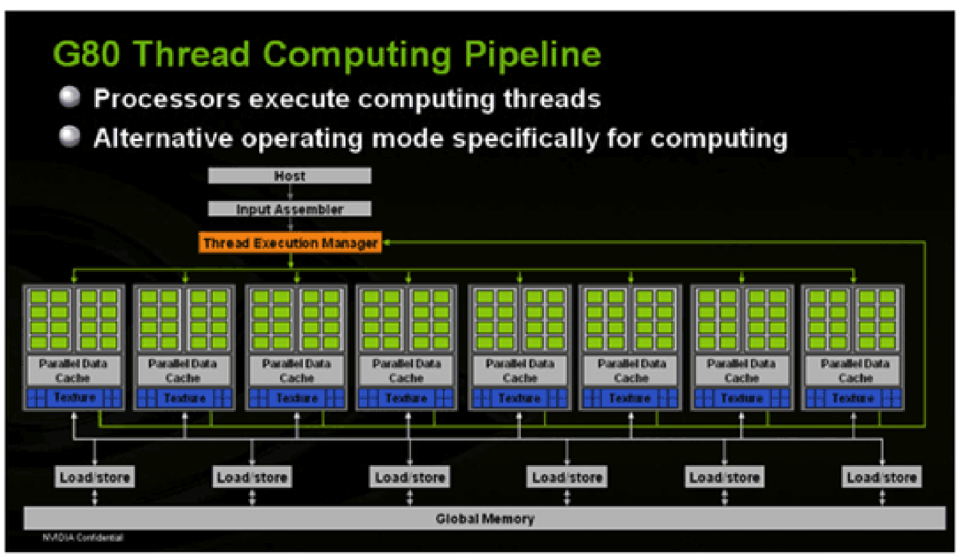
- IoT decision making process is as local as it is centralized. This means that IoT processing has to depend on decision making in two distinct places.
  - One in a centralized Cloud repository
  - A localized decision making process that predicts the events that takes a quicker decision much

- Local: High computation Speed, More Secure
- Cloud: High computation Power, Less Secure

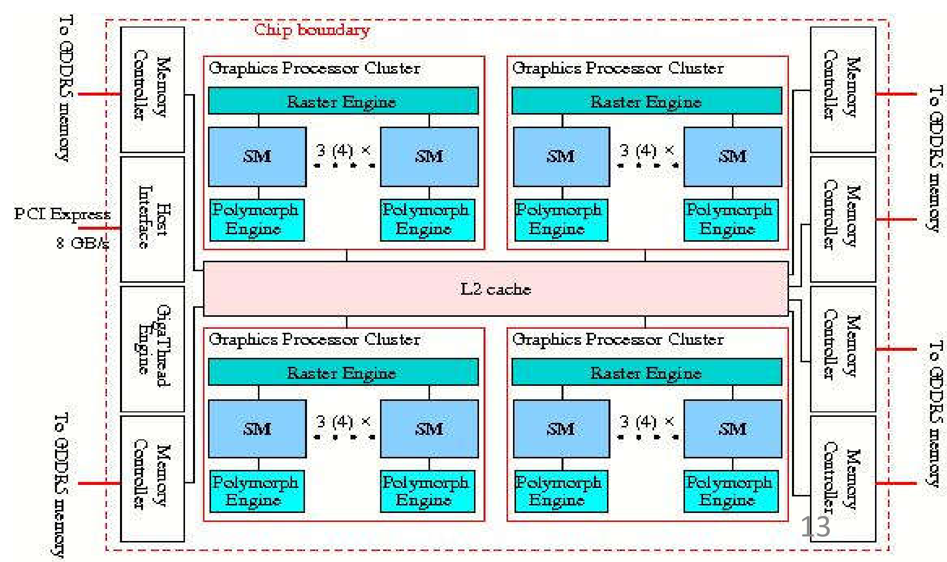
## GPU : graphic processing unit

Quadro -K6000

Gforce –G80

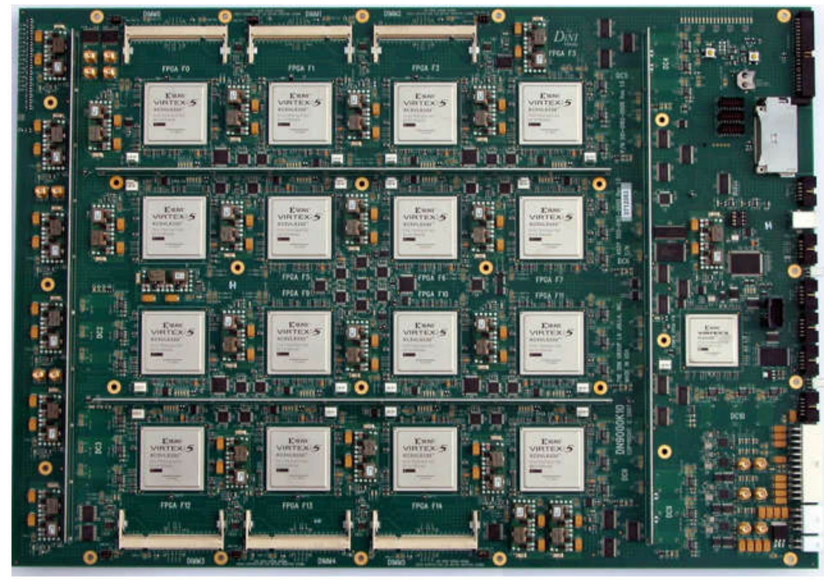



Tesla C2050




SM: Streaming Multiprocessor

## FPGA ACCELERATED COMPUTING



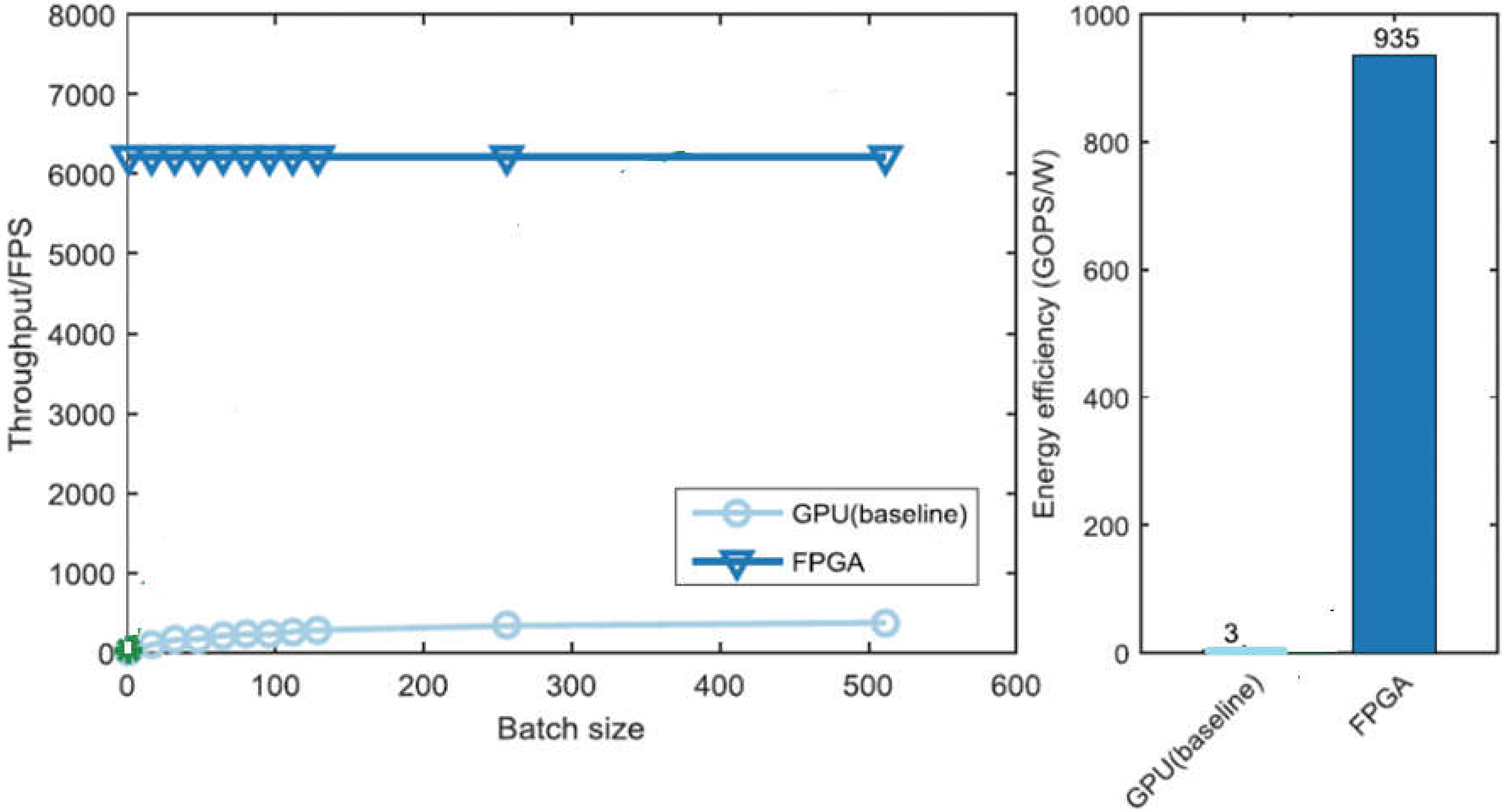
**Web Services Cloud**

1)Custom Hardware Acceleration in the AWS Cloud (AWS:Amazon)

2) Huawei

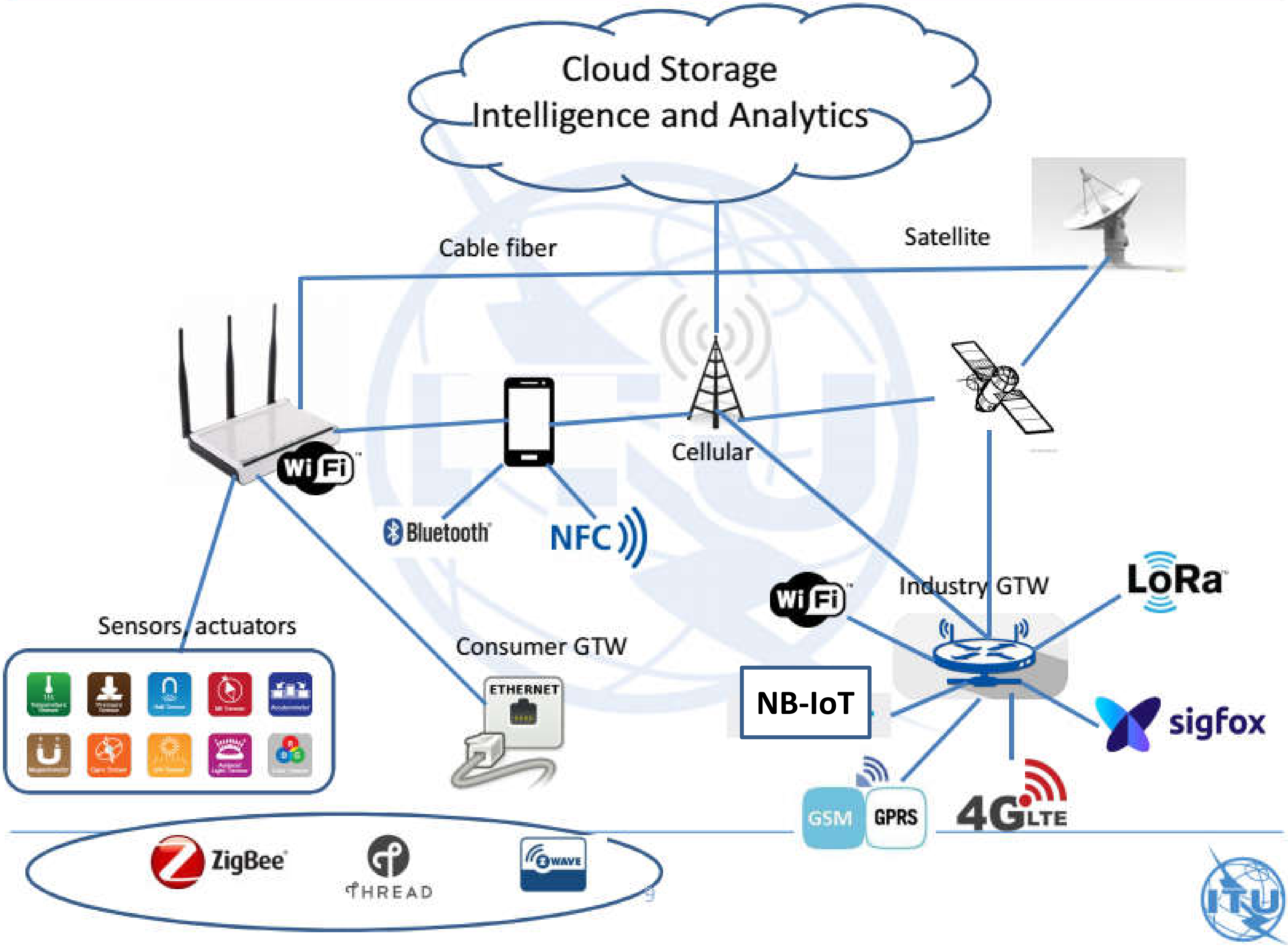
3) Alibaba Cloud

4) Nimbix Cloud




Throughput and energy efficiency comparison with GPU and FPGA implementations

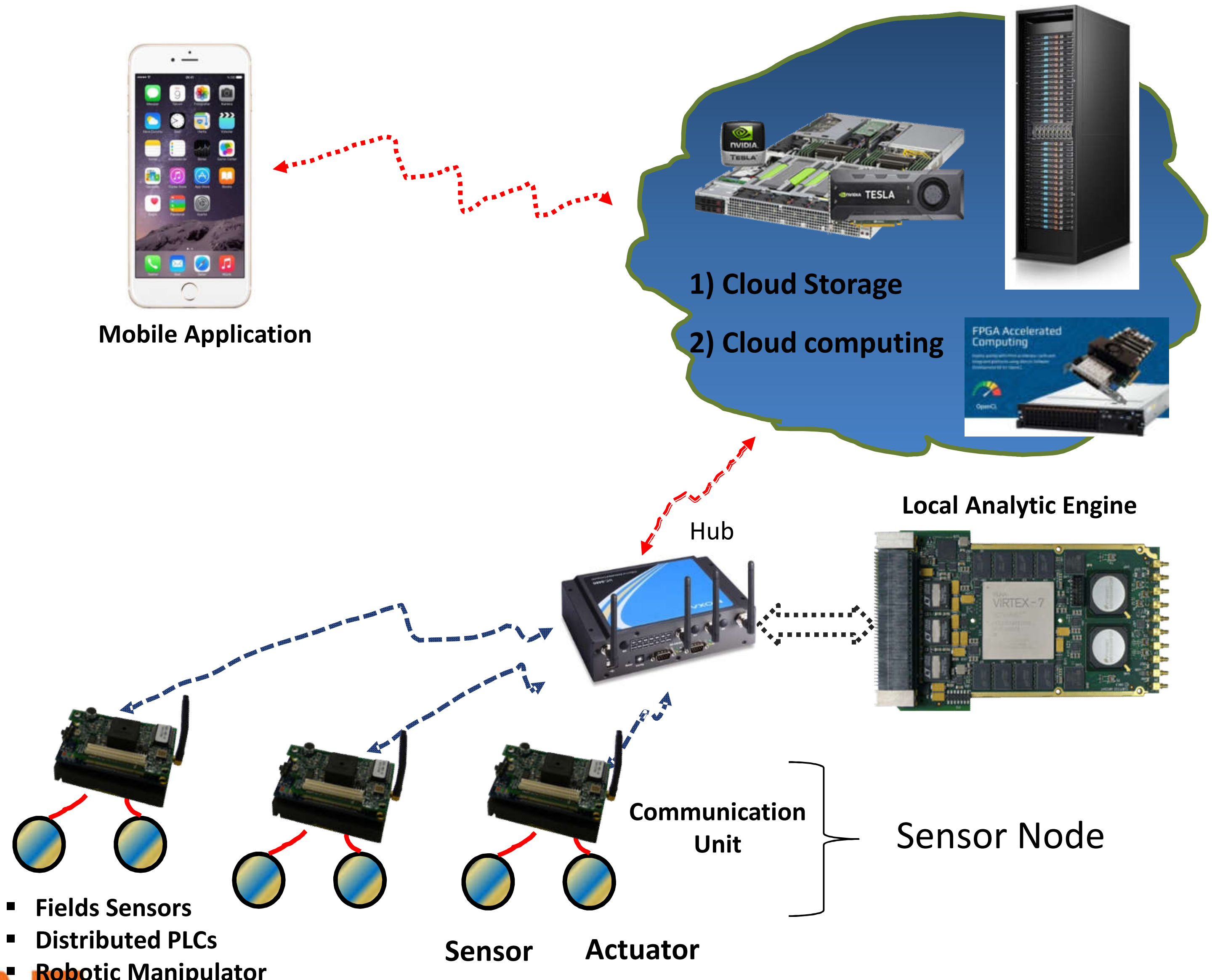
# IoT network general architecture



***IoT communications*** are or should be:

- Low **cost**,
- Low **power**,
- Long **battery duration**,
- High **number of connections**,
- Low **bitrate**,
- Long **range**,
- Low **processing capacity**,
- Low **storage capacity**,
- Small **size devices**,
- Simple **network architecture** and **protocols**.

# Basic elements of an IoT infrastructure



# IoT vs IIoT

| | IOT | IIOT |
|---|---|---|
| FOCUS ON | Convenience for individual consumers. | Return on investment by improving efficiency, safety, and productivity. |
| SYSTEM BREAKDOWN | Do not immediately create emergency situation. Important but not critical. | Often creates life threatening or other emergency situations. Mission critical. |
| DRIVING PHILOSOPHY | Human Productivity | Machine Productivity |
| APPLICATIONS | Consumer level-devices :<br>▪ Wearable fitness tools<br>▪ Smart home thermometers | Systems used in high stakes industries :<br>▪ Manufacturing<br>▪ Aerospace<br>▪ Defences<br>▪ Energy |

# Gartner on IoT Platforms

"Through 2018, there will be no dominant IoT ecosystem platform; IT leaders will still need to compose IoT solutions from multiple providers.

This challenge is even more acute because IoT solutions are not clearly understood and are relatively immature, IoT standards either don't exist or are still immature, and vendors are taking advantage of this "wild west" moment in IoT adoption to advance their own agendas and points of view.

No one IoT architectural approach will meet the diverse business and technology requirements for all IoT projects."

Gartner 2015

# GE PREDIX PLATFORM IS THE ENABLER

## Cloud-based platform for Industrial Internet

+

## Capabilities for Industrial companies

+ Alstom Grid

Over 200 years
combined experience in providing advanced energy solutions

- Connected assets
- Industrial data management
- Industrial data science
- Cloud & mobile

- Monitoring & diagnostics
- Asset lifecycle
- Predictive maintenance
- Operations & intelligence

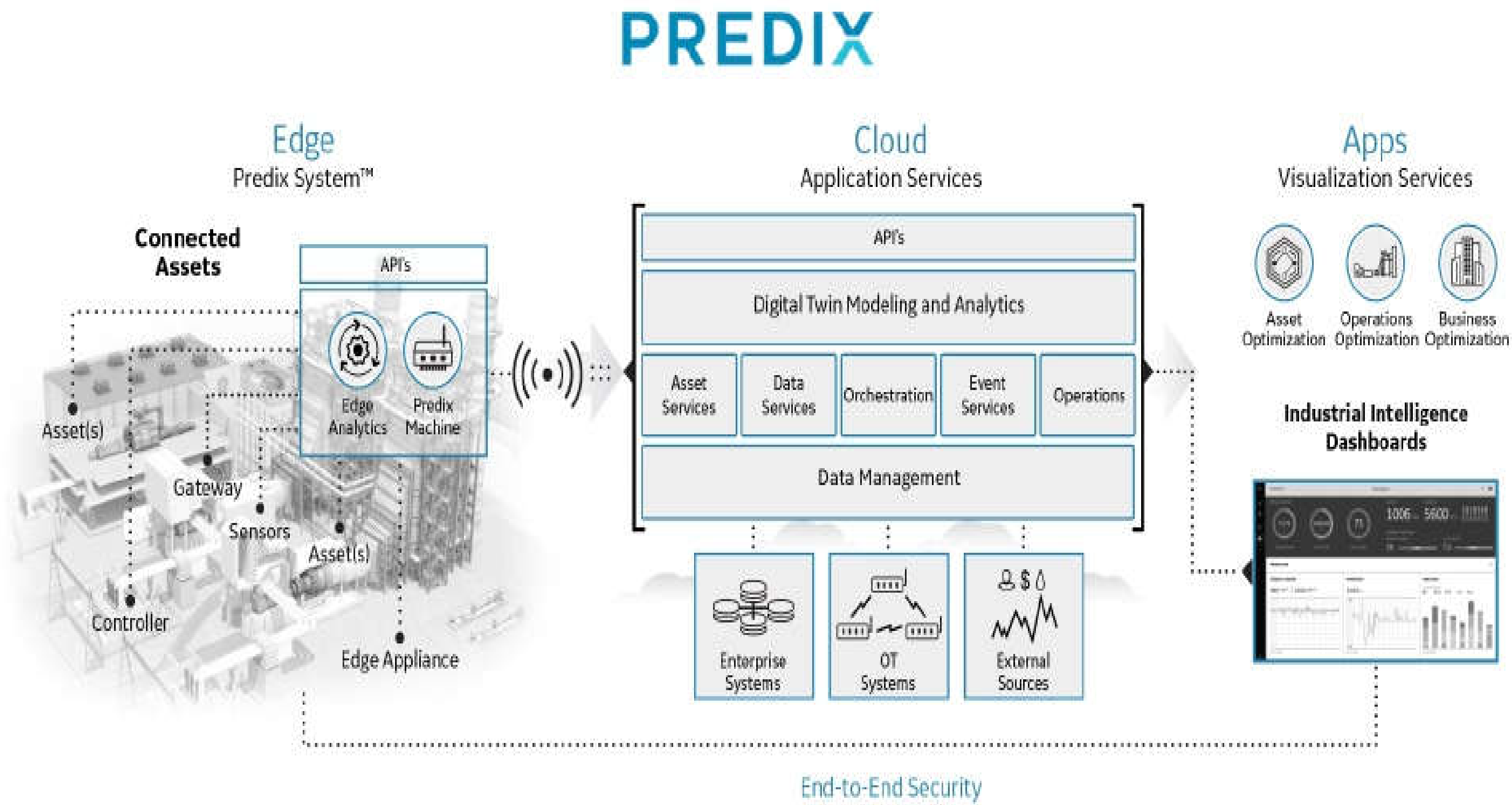
**Reliability**
Increase availability and longer asset life

**Cost reduction**
Lower operating costs with greater efficiencies

**Risk mitigation**
Lower operations and financial risk

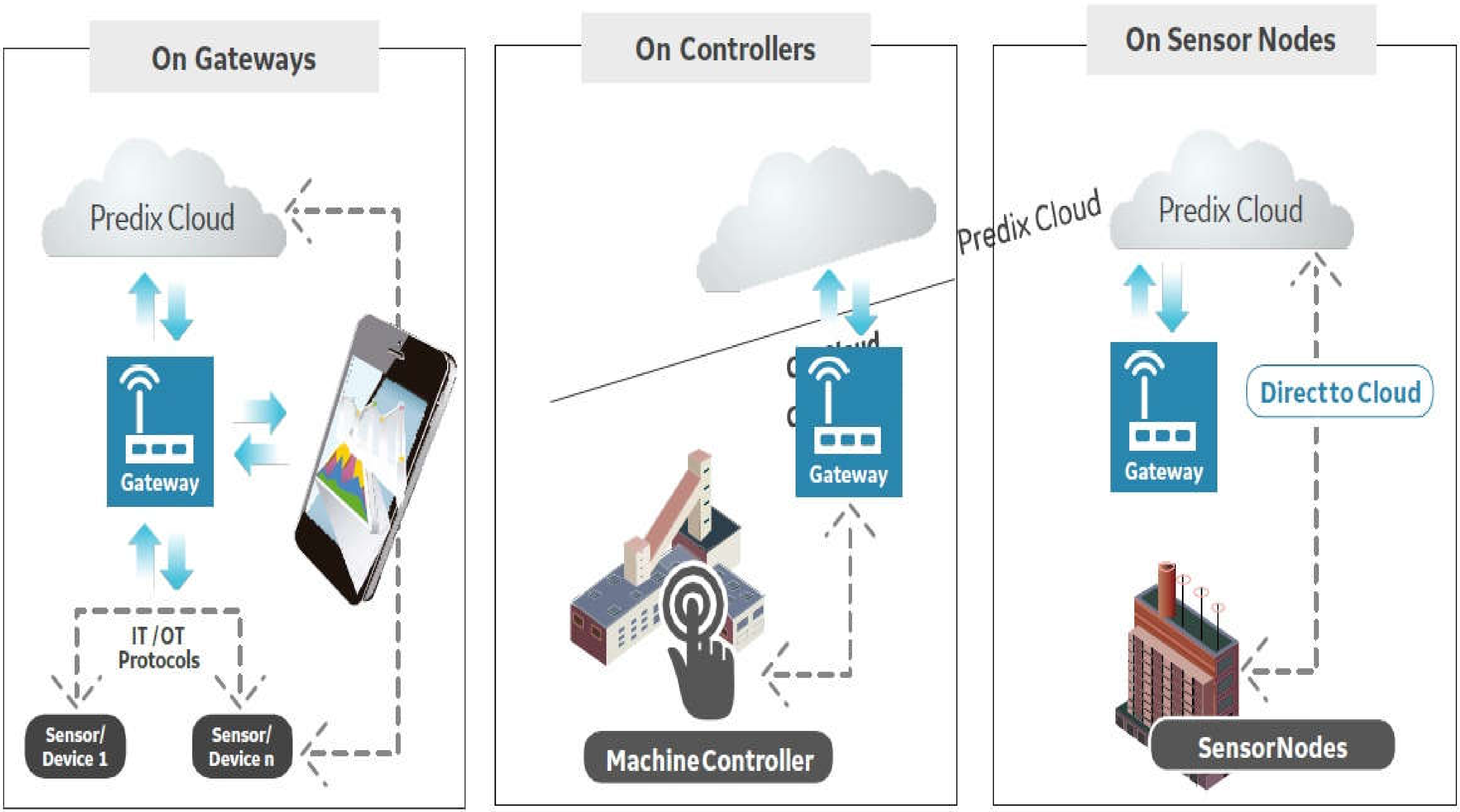
**Profitable growth**
Increase production for market advancement

# Real world computing from edge-to-cloud

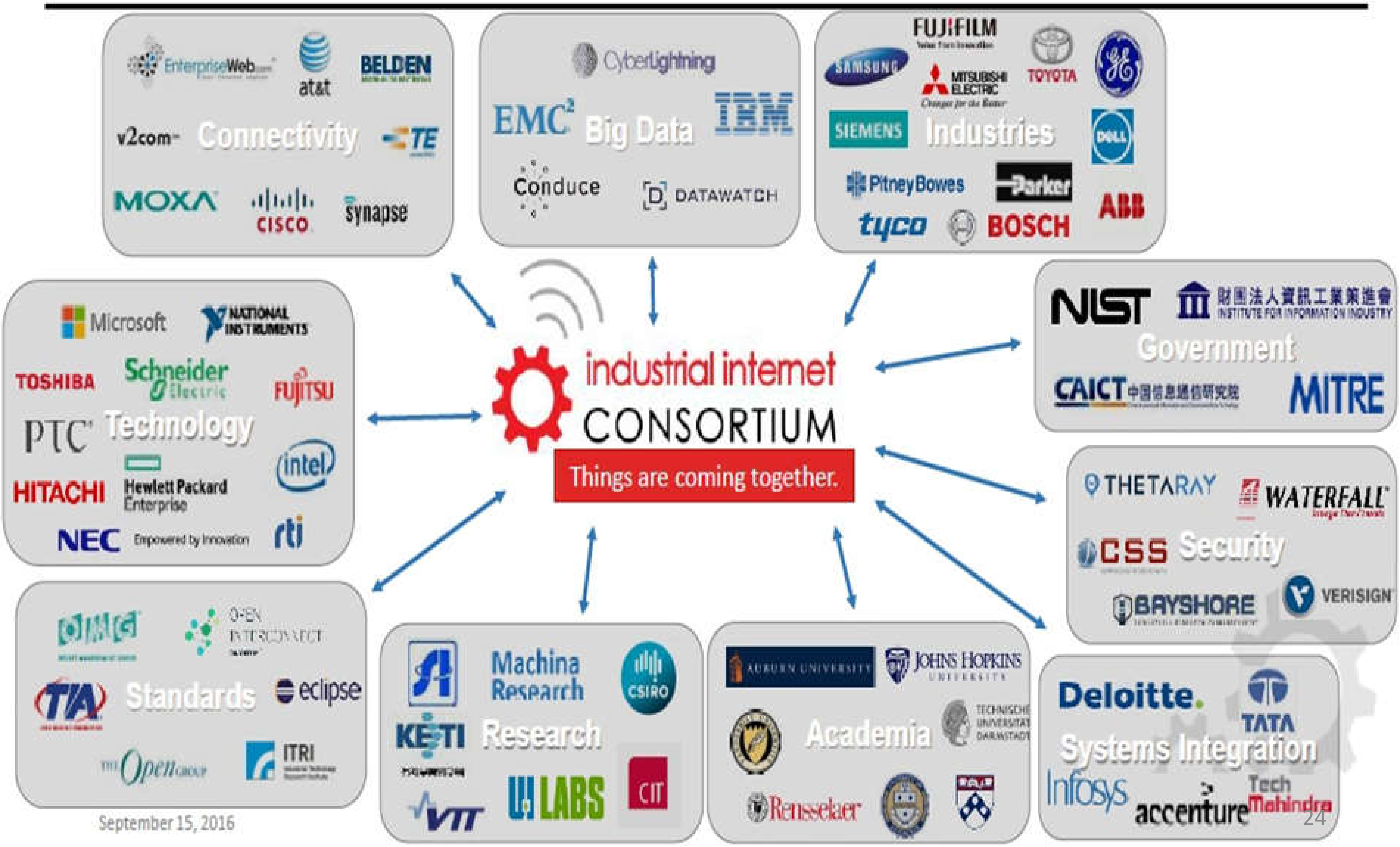


# Deployment Models

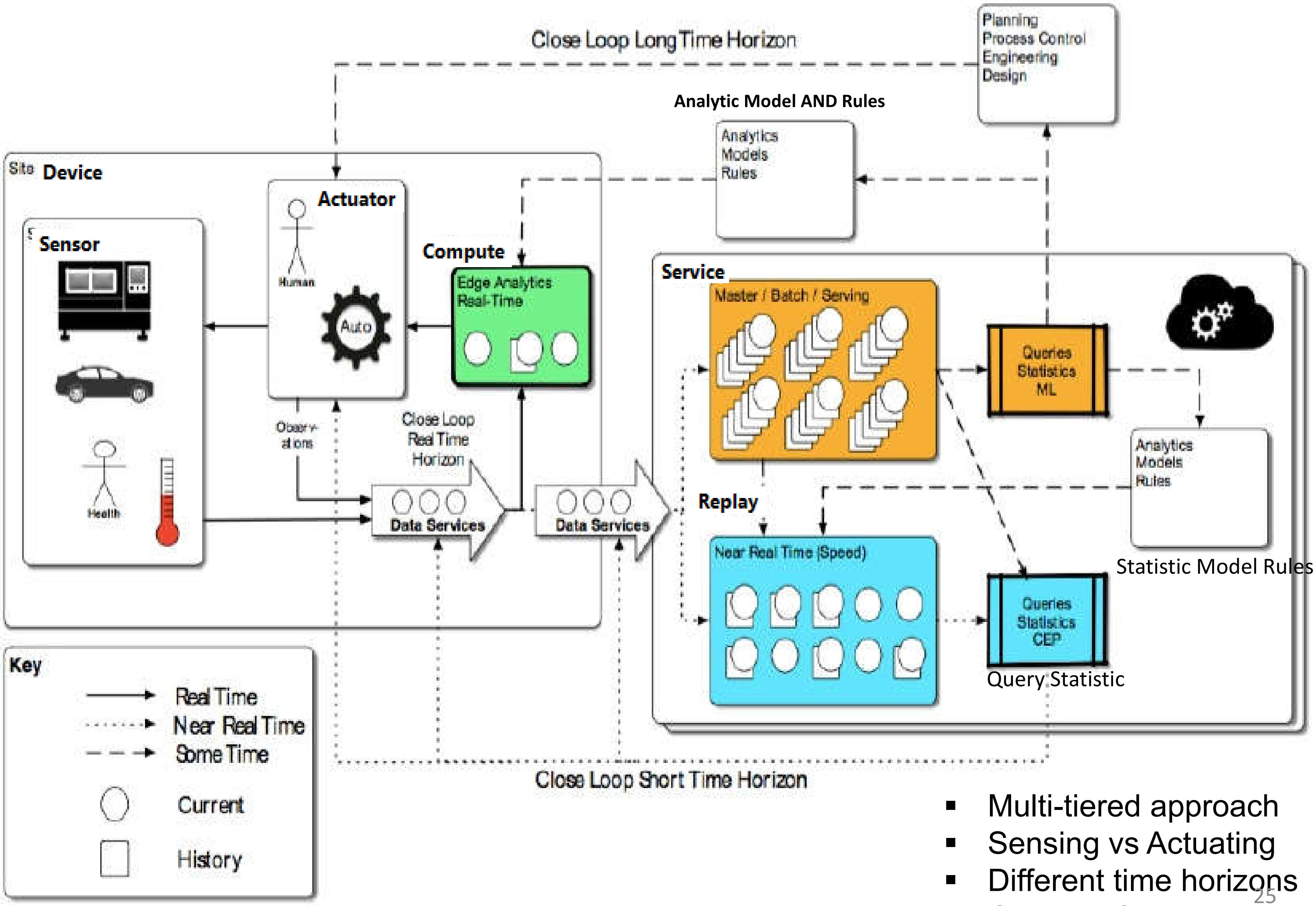
The Predix Machine software can be deployed in three ways



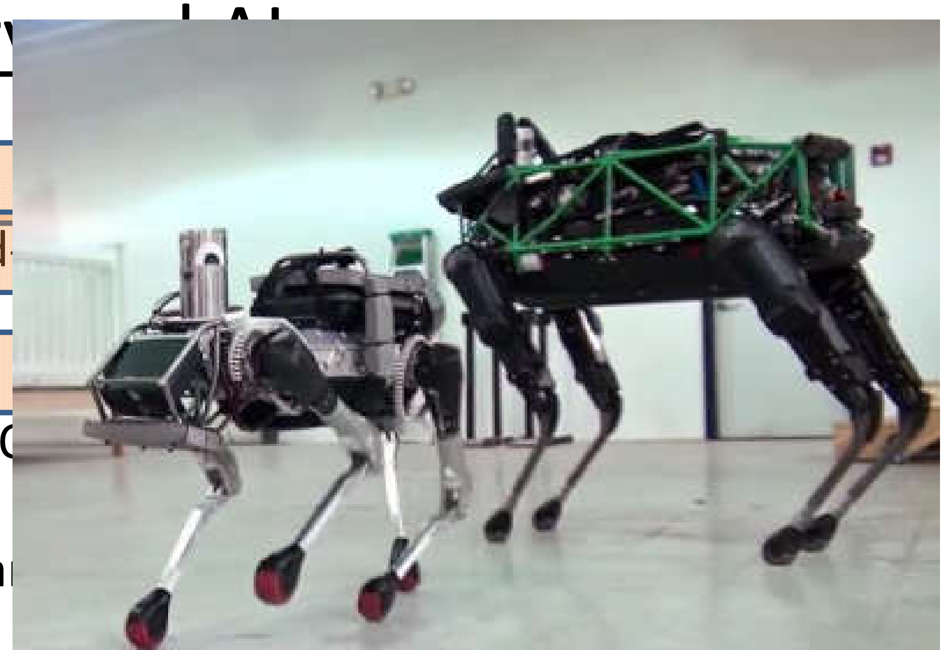
# The IIC: Things are coming together



## IIC's reference model for industrial analytics covers most of the bases




- Multi-tiered approach
- Sensing vs Actuating
- Different time horizons
- Open vs Closed loop



lge base control

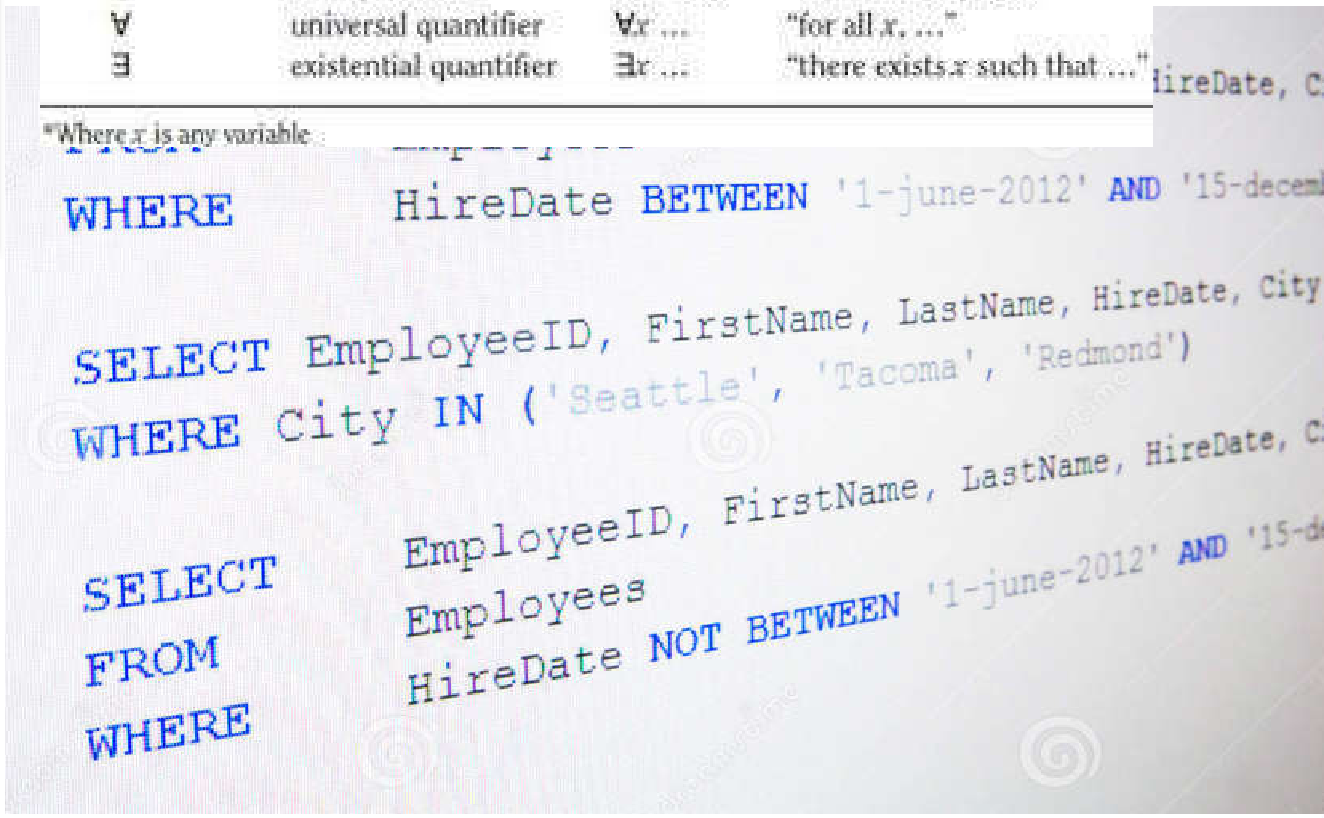
High Level Control

**Controller vs Observer**

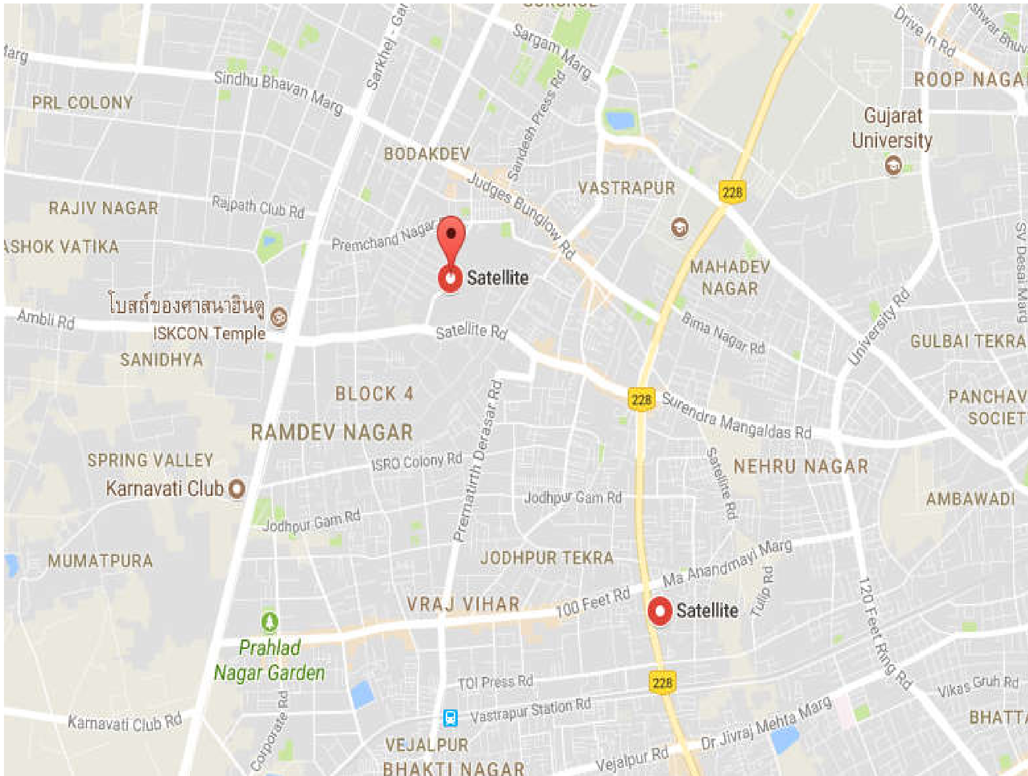
## Expert System;


| Symbol | Name | Usage | Meaning* |
|---|---|---|---|
| & | conjunction | ... & ... | "both ... and ..." |
| ∨ | disjunction | ... ∨ ... | "either ... or ... (or both)" |
| ~ | negation | ~... | "it is not the case that ..." |
| ⊃ | implication | ... ⊃ ... | "if ... then ..." |
| ≡ | bi-implication | ... ≡ ... | "... if and only if ..." |
| ∀ | universal quantifier | ∀x ... | "for all x, ..." |
| ∃ | existential quantifier | ∃x ... | "there exists x such that ..." |

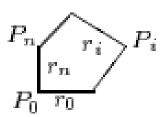
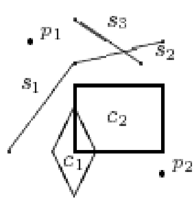
*Where x is any variable




- Predicated Calculus
- Second Order Predicated Calculus




Euclidean Plane in $\Phi_P$

| | | Representation using gen. tuples in $\Phi_P{}^a$ |
|---|---|---|
| | | $C_{point}(p) \equiv (X - x = 0) \wedge (Y - y = 0) \wedge (N = c_{id})^b$ |
| | | $C_{segment}(s) \equiv (x_1 - X \leq 0) \wedge (X - x_2 \leq 0) \wedge (aX + bY + c = 0) \wedge (N = c_{id})^c$ |
|  | $c = \begin{cases} P_i = (x_i, y_i) \\ r_i : a_i X + b_i Y + c_i = 0 \\ i = 0, \ldots, n \end{cases}$ | $C_{convex}(c) \equiv (sign(P_1, P_2) a_1 X + b_1 Y + c_1 \geq 0) \wedge \ldots \wedge (sign(P_{n-1}, P_n) a_n X + b_n Y + c_n \geq 0)^d \wedge (N = c_{id})$ |
| COMPOSITE (csp)  | $csp = (p_1 \cup \ldots \cup p_n) \cup (s_1 \cup \ldots \cup s_m) \cup (c_1 \cup \ldots \cup c_l)$ | $C_{composite}(csp) \equiv \{C_{point}(p_1) \wedge N = c_{id}, \ldots, C_{point}(p_n) \wedge N = c_{id}\} \cup \{C_{segment}(s_1) \wedge N = c_{id}, \ldots, C_{segment}(s_m) \wedge N = c_{id}\} \cup \{C_{convex}(c_1) \wedge N = c_{id}, \ldots, C_{convex}(c_l) \wedge N = c_{id}\}$ |

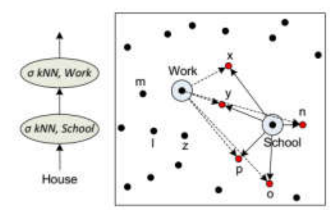
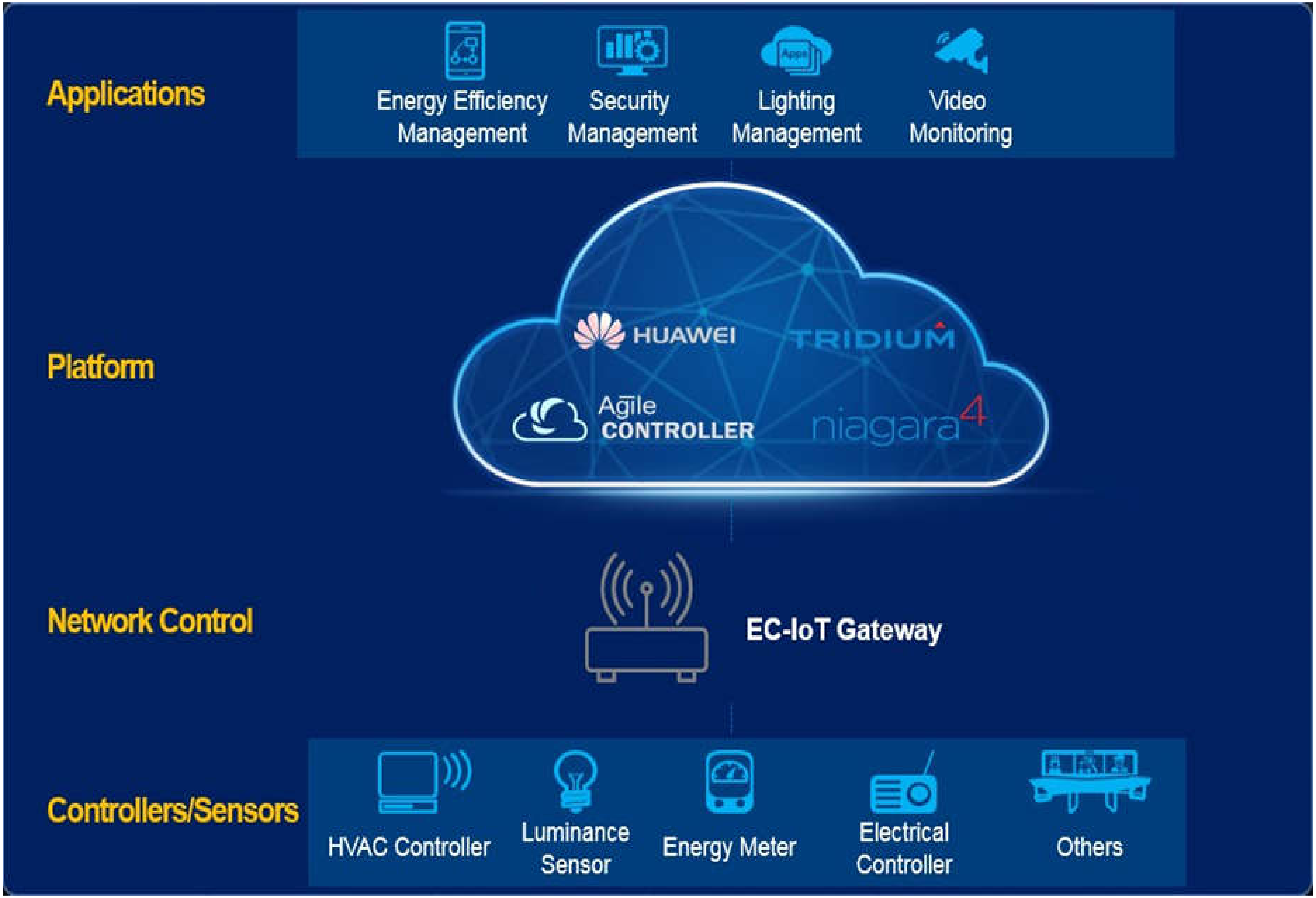
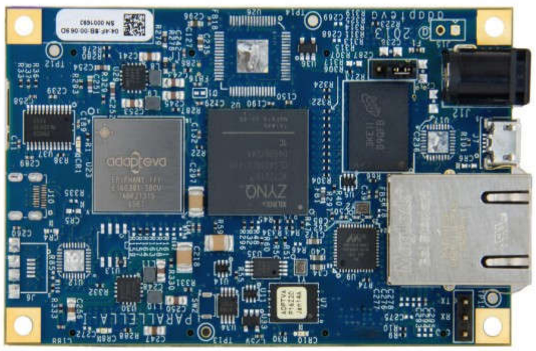



**Figure 15: A QEP with $\sigma_{kNN,School}(House)$ performed before $\sigma_{kNN,Work}(House)$. The resulting houses are: $x$, $y$, $n$, $p$, and $o$.**

## EC-IoT Smart Building Solution

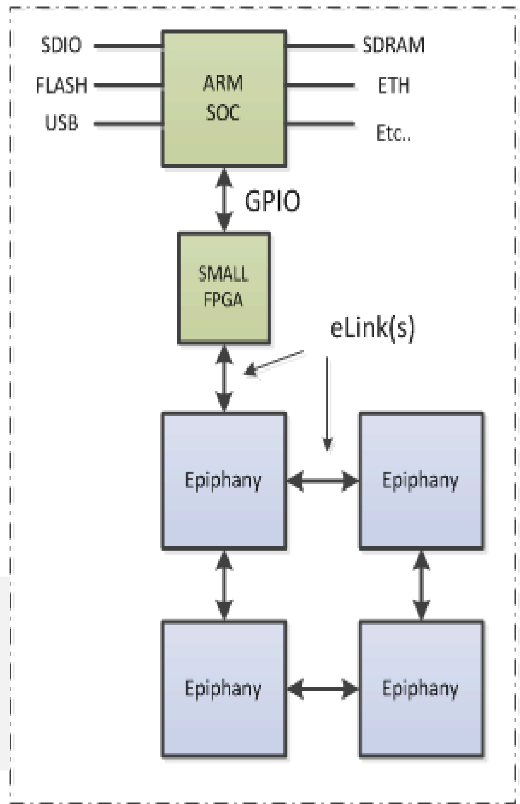


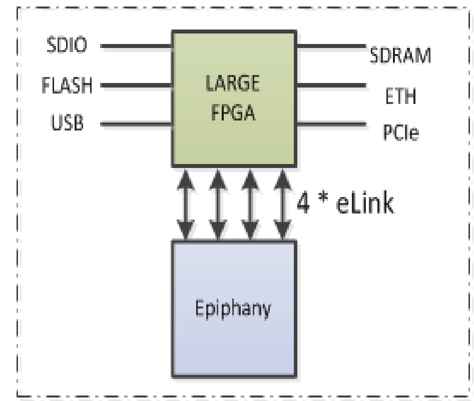
# Example Local Analytic Engine (The Parallella Computer: [Adapteva]())

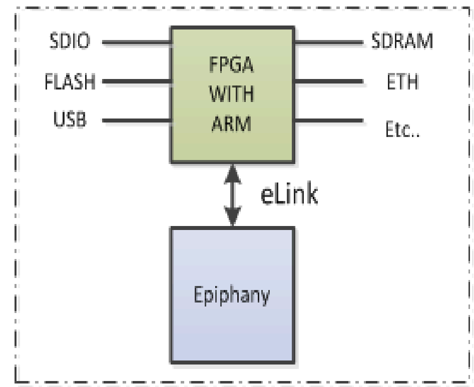


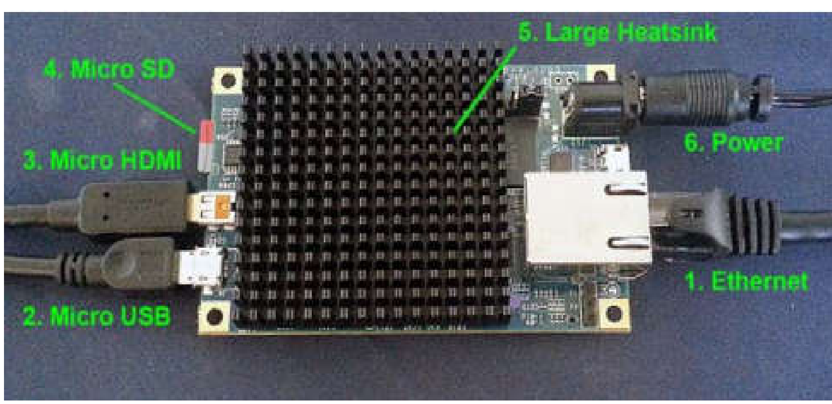
- 18-core credit card sized computer
- #1 in energy efficiency @ 5W
- 16-core Epiphany RISC SOC
- Zynq SOC (FPGA + ARM A9)
- Gigabit Ethernet
- 1GB SDRAM
- Micro-SD storage
- Up to 48 GPIO pins
- HDMI, USB (optional)
- Open source design files
- Runs Linux
- Starting at $99

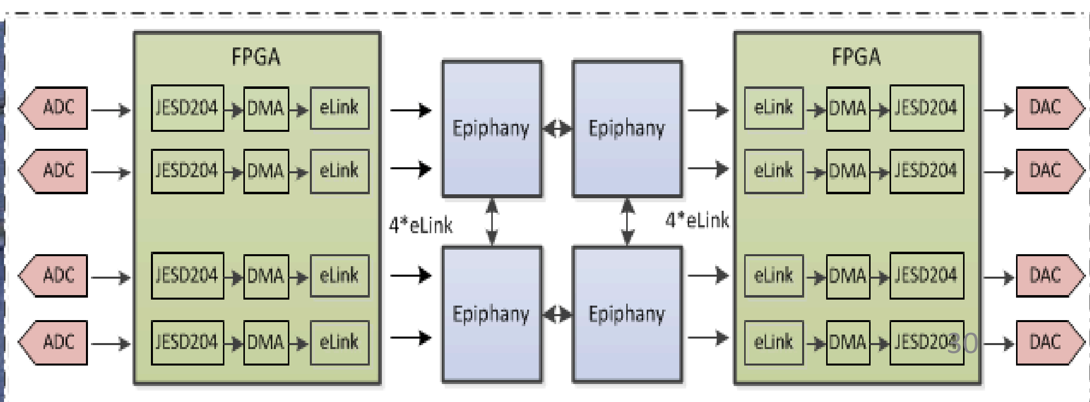
a scalable array of simple RISC processors programmable in bare metal C/C++ or in a parallel programming frameworks like OpenCL, MPI, and OpenMP.

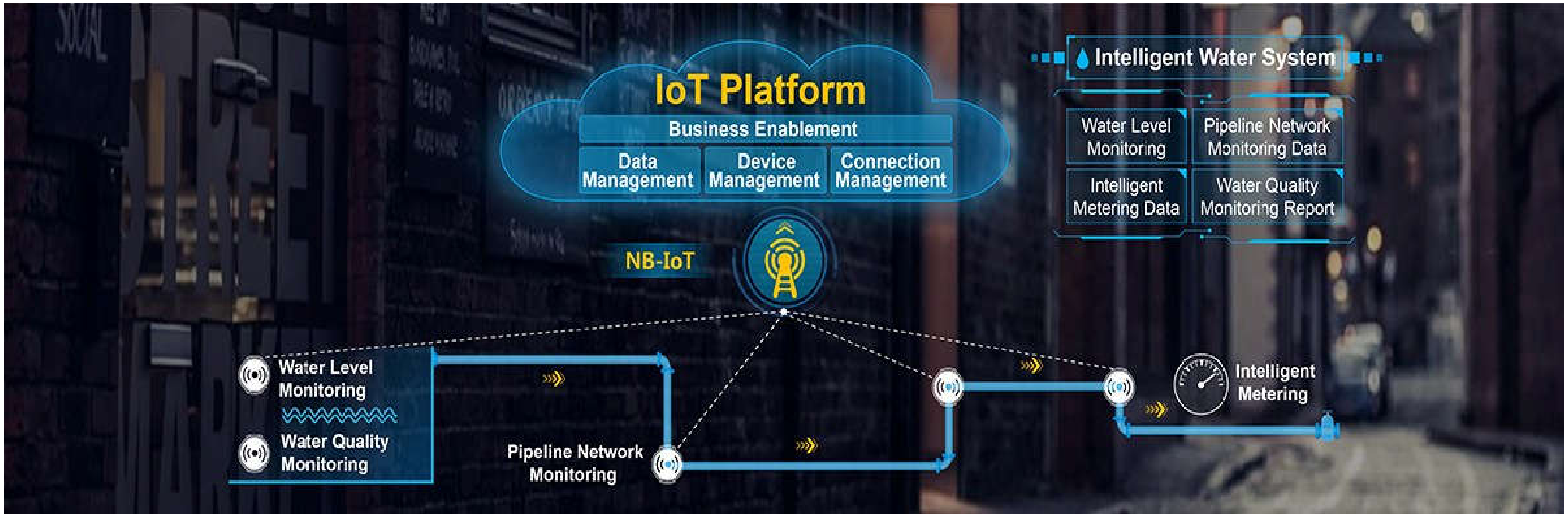


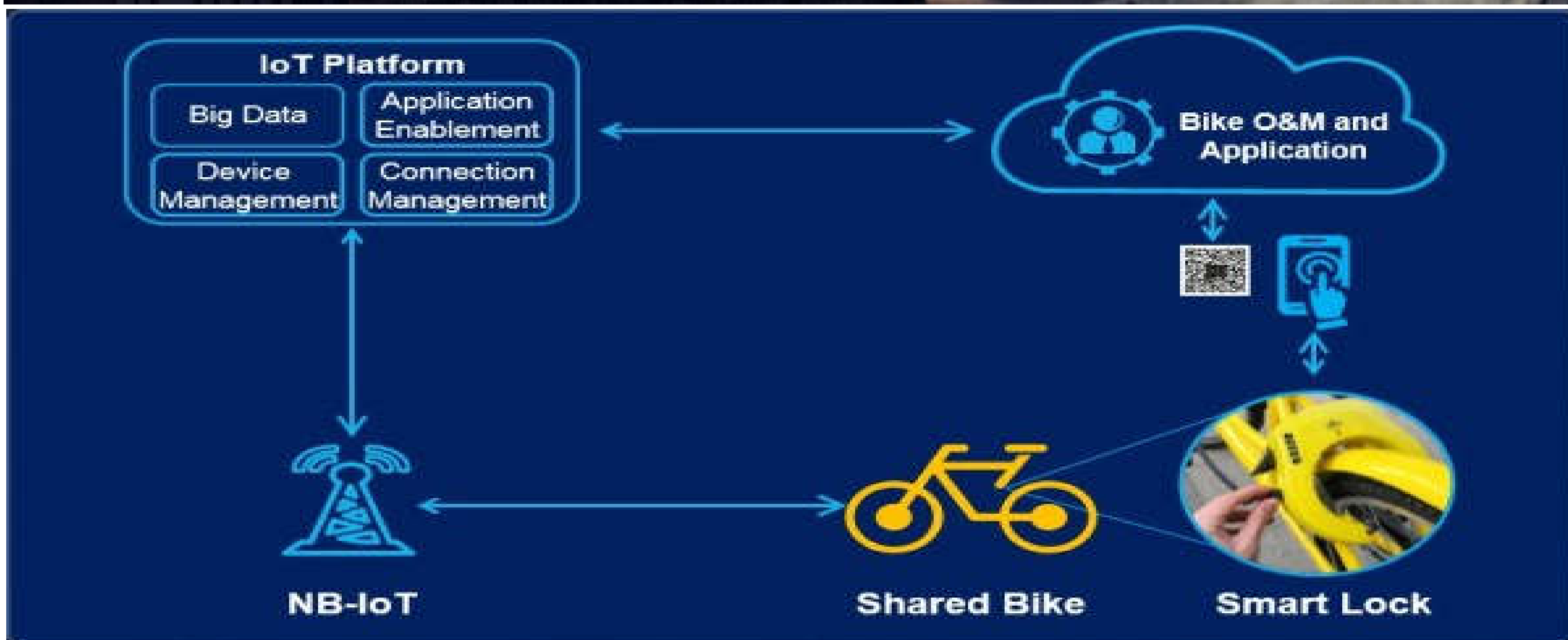



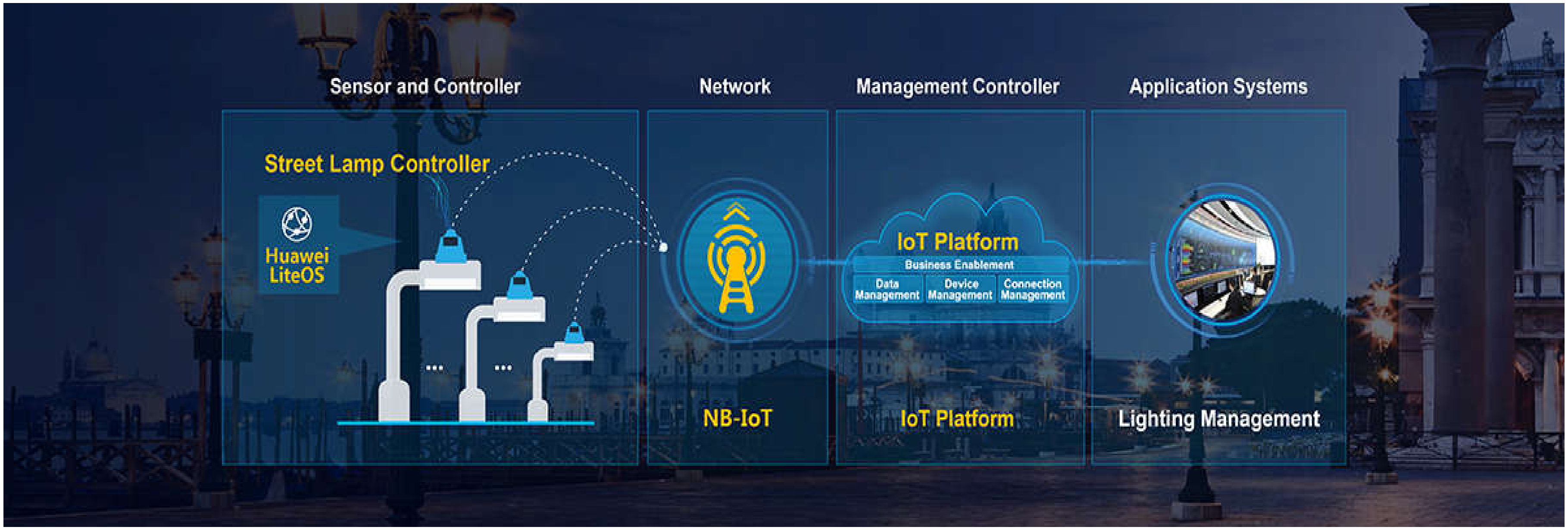



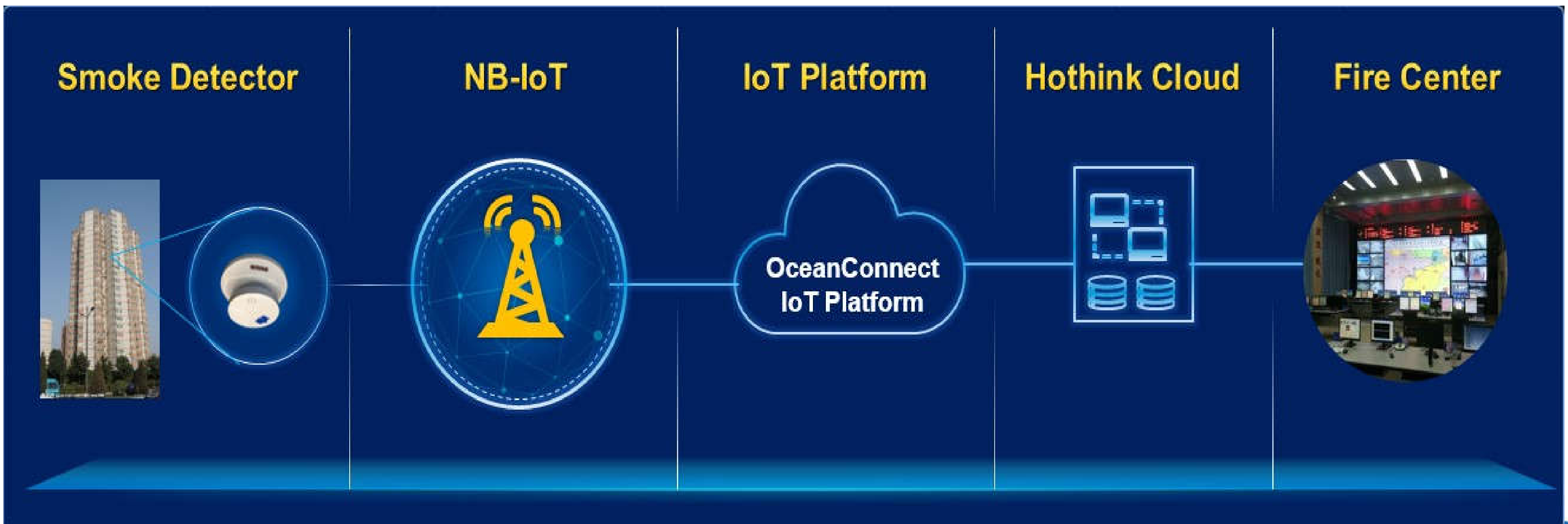




IoT Platform
Business Enablement
Data Management
Device Management
Connection Management
NB-IoT
Intelligent Water System
Water Level Monitoring
Pipeline Network Monitoring Data
Intelligent Metering Data
Water Quality Monitoring Report
Water Level Monitoring
Water Quality Monitoring
Pipeline Network Monitoring
Intelligent Metering


IoT Platform
Big Data
Application Enablement
Device Management
Connection Management
Bike O&M and Application
NB-IoT
Shared Bike
Smart Lock

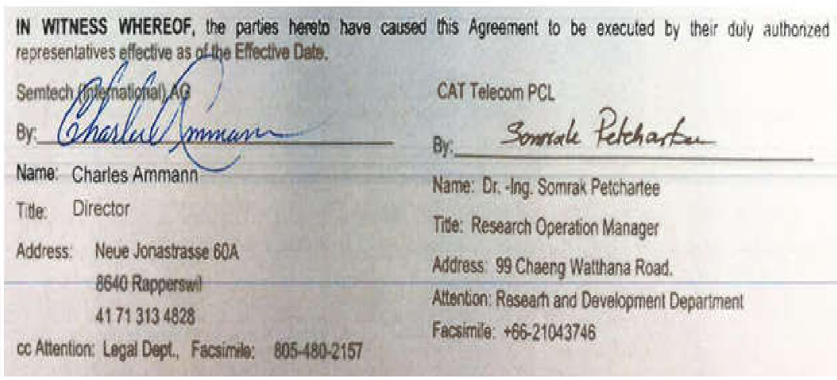

Sensor and Controller
Network
Management Controller
Application Systems
Street Lamp Controller
Huawei LiteOS
IoT Platform
Business Enablement
Data Management
Device Management
Connection Management
NB-IoT
IoT Platform
Lighting Management


Smoke Detector
NB-IoT
IoT Platform
Hothink Cloud
Fire Center
OceanConnect IoT Platform


SUPPLY CHAIN &
LOGISTICS
HEALTHCARE
METERING
INDUSTRIAL
CONTROL
ENVIRONMENT
CITIES
HOME &
BUILDINGS

SEMTECH

NON-DISCLOSURE AGREEMENT
(General)



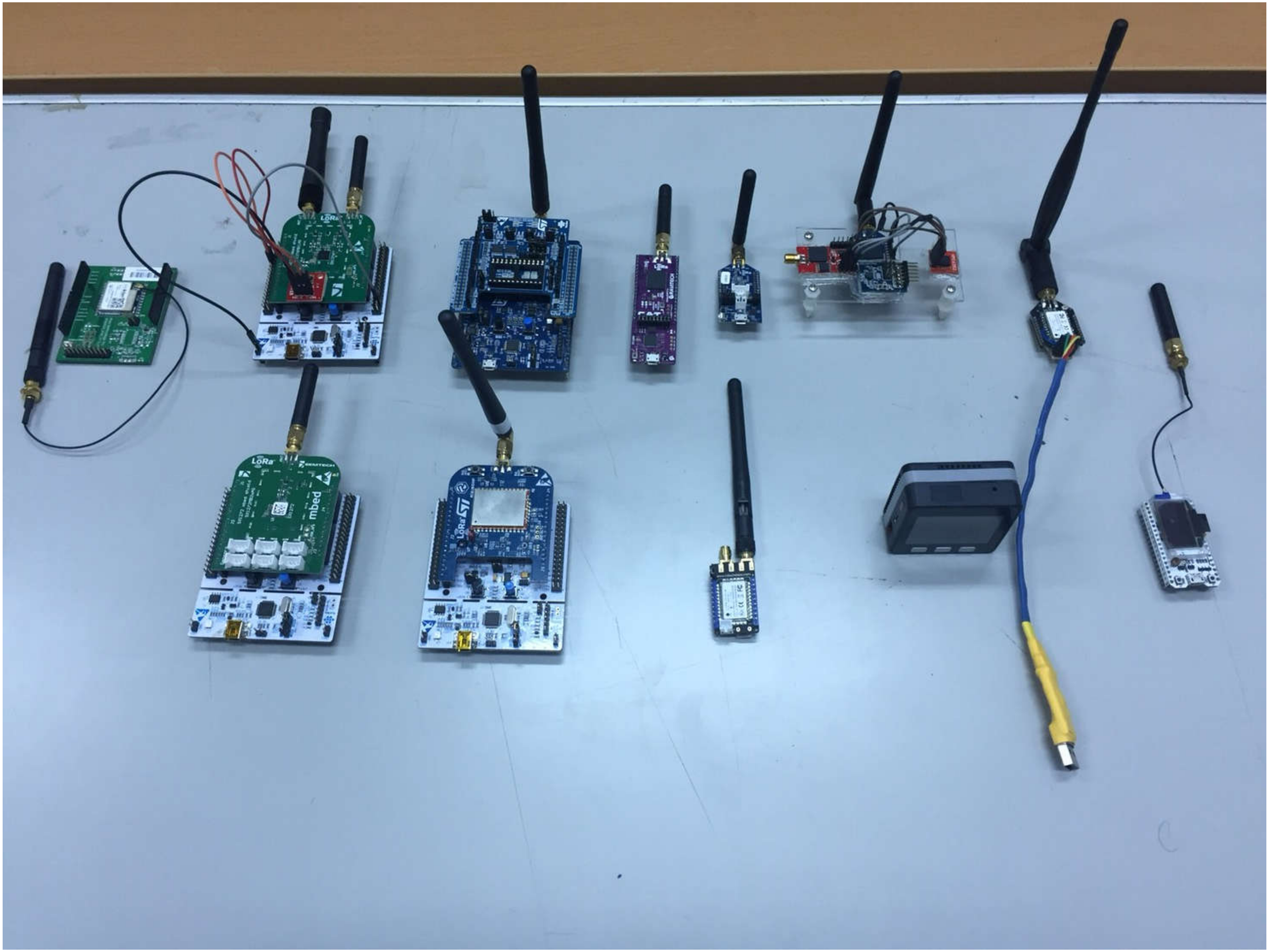
IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed by their duly authorized representatives effective as of the Effective Date.

Semtech (International) AG
By: Charles Ammann
Name: Charles Ammann
Title: Director
Address: Neue Jonastrasse 60A
8640 Rapperswil
41 71 313 4828
cc Attention: Legal Dept., Facsimile: 805-480-2157

CAT Telecom PCL
By: Somrak Petchartee
Name: Dr.-Ing. Somrak Petchartee
Title: Research Operation Manager
Address: 99 Chaeng Watthana Road.
Attention: Research and Development Department
Facsimile: +66-21043746


## LoRa Alliance NetID Allocation Table

| Available NetIDs allocated to Contributor (and Adopter-to-upgrade) Members only | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Operator/Network name** | **Membership level** | **Current membership expiration date** | **Date on the signed application form** | **Date the request received from help@lora-alliance.org** | **Assignment date** | **Contact person** | **Status** |
| SenSys | Adopter | 5/17/2018 | 11/3/2017 | 11/9/2017 | 11/14/2017 | Warwick Jones (warwick@sensys.co.nz) | Provisionally allocated (needs higher membership level) |
| CAT Telecom | Adopter | 8/25/2018 | 10/31/2017 | 11/3/2017 | 11/14/2017 | Somrak Petchartee (somrak.p@cattelecom.com) | Provisionally allocated (needs higher membership level) |
| Spark | Adopter | 10/24/2018 | 10/31/2017 | 11/3/2017 | 11/14/2017 | andrew.leckie@sparkventures.co.nz | Provisionally allocated (needs higher membership level) |


LoRa
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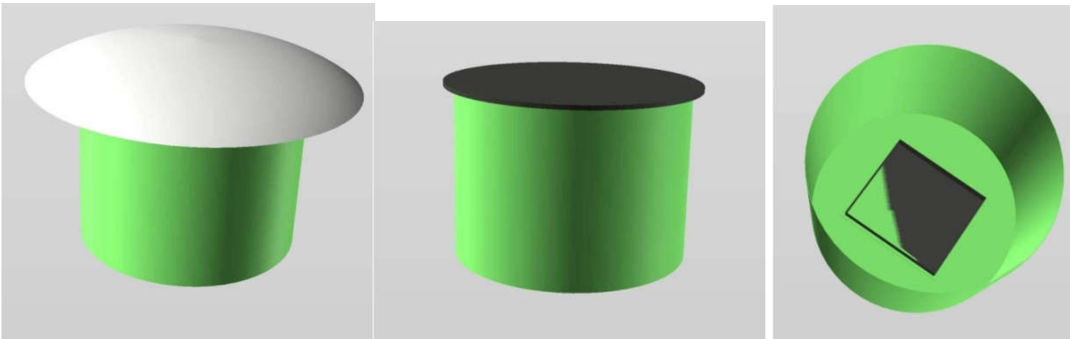
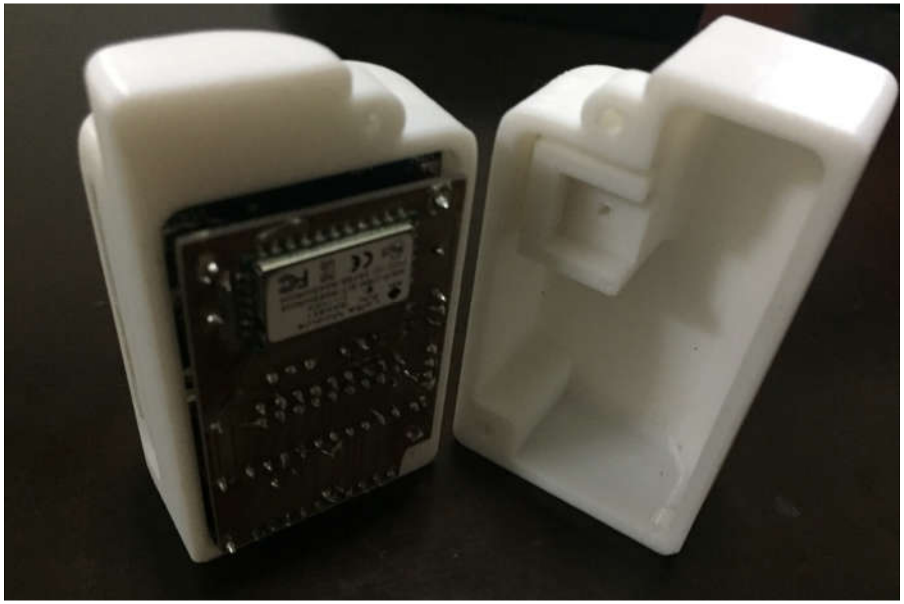
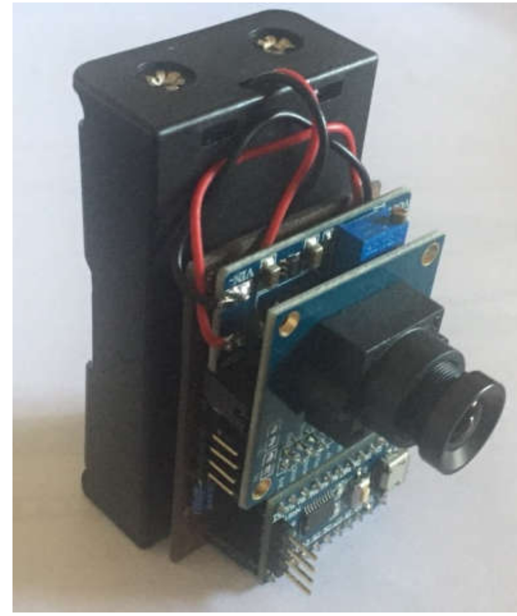
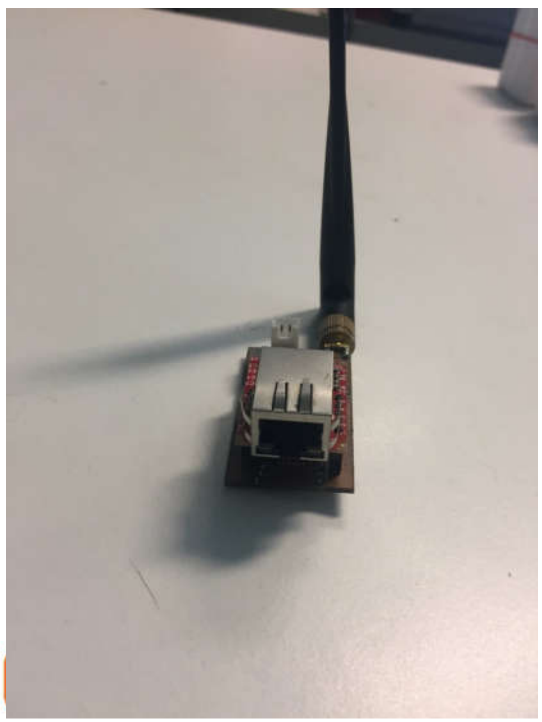
# LoRa Smart Parking Sensor







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Lab
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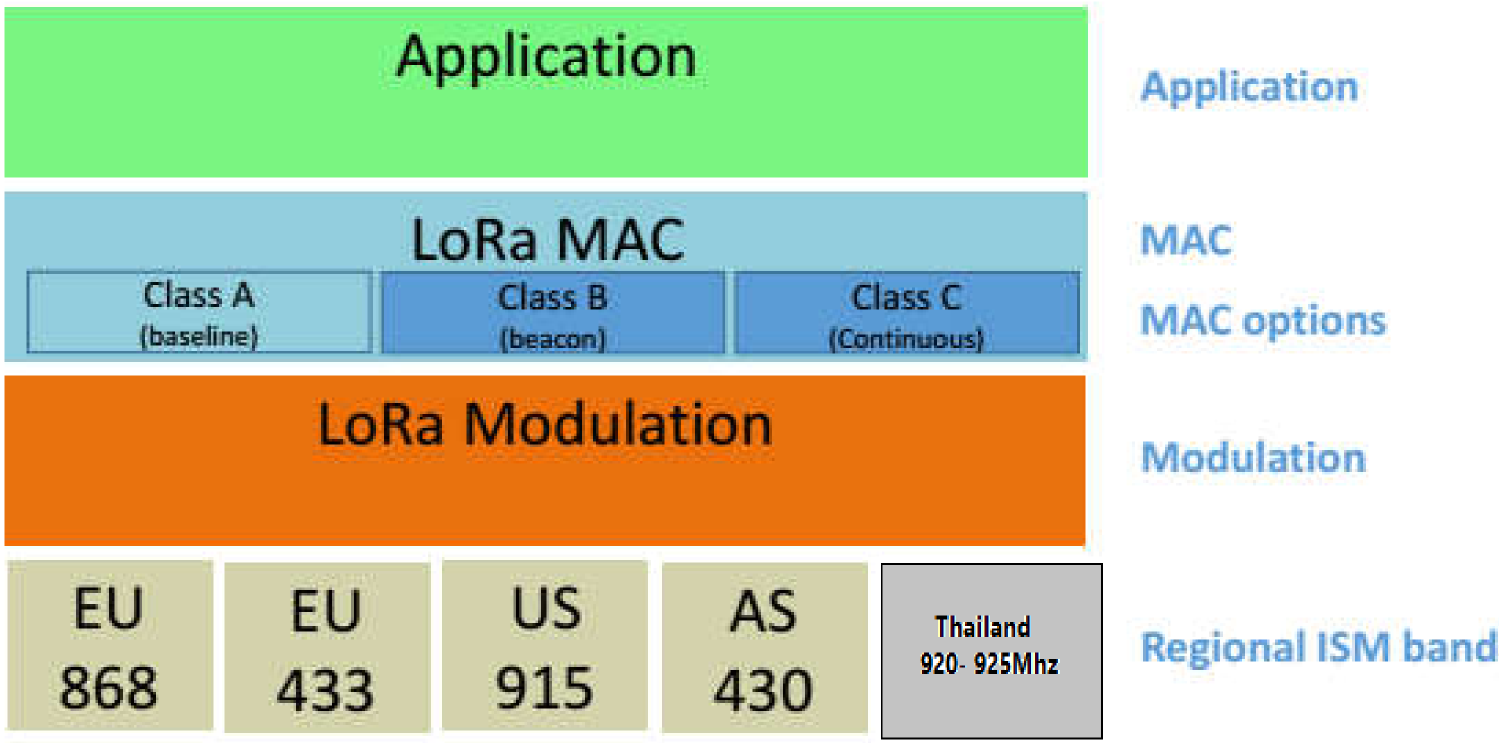
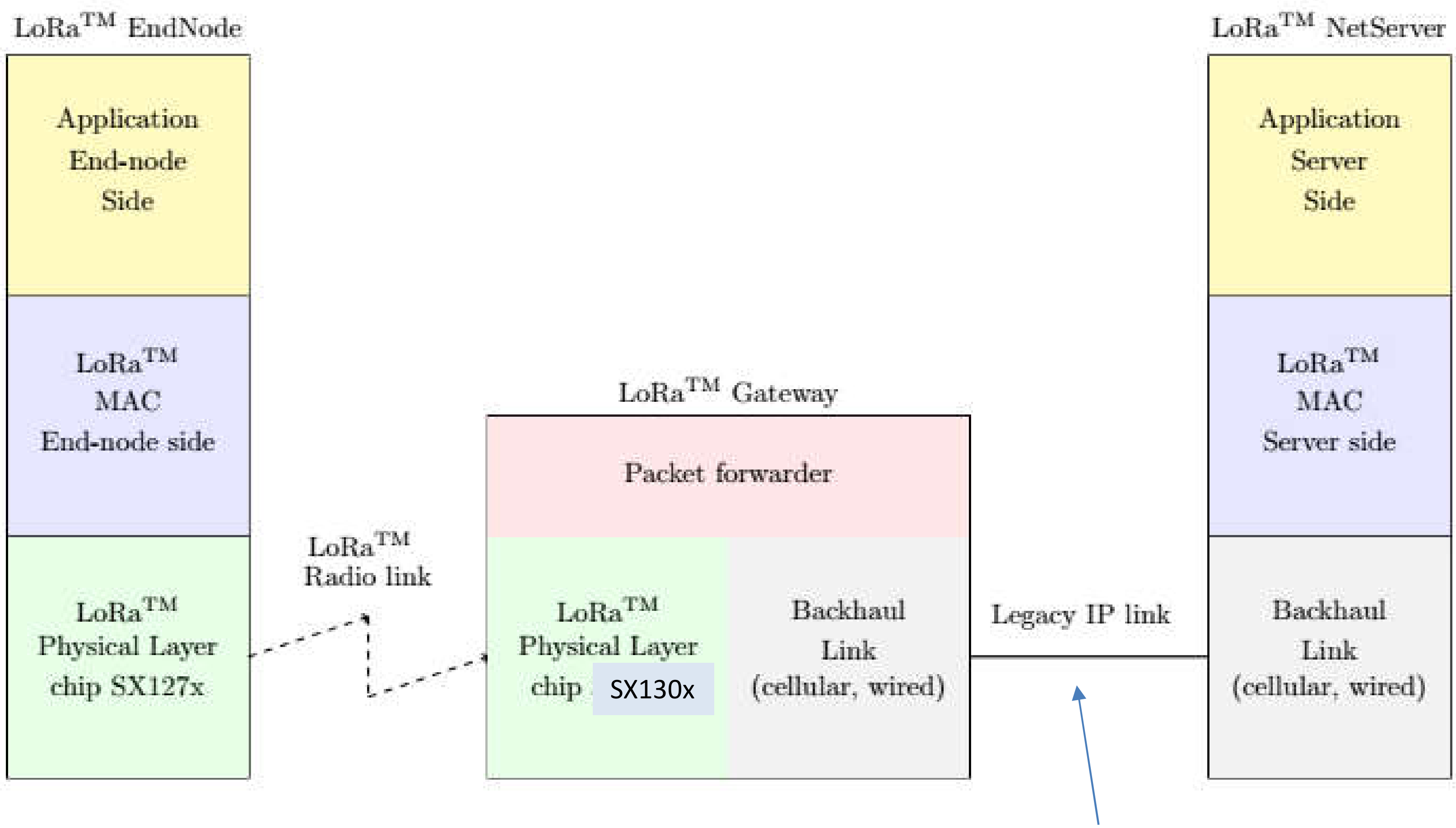
# LoRaWAN Classes

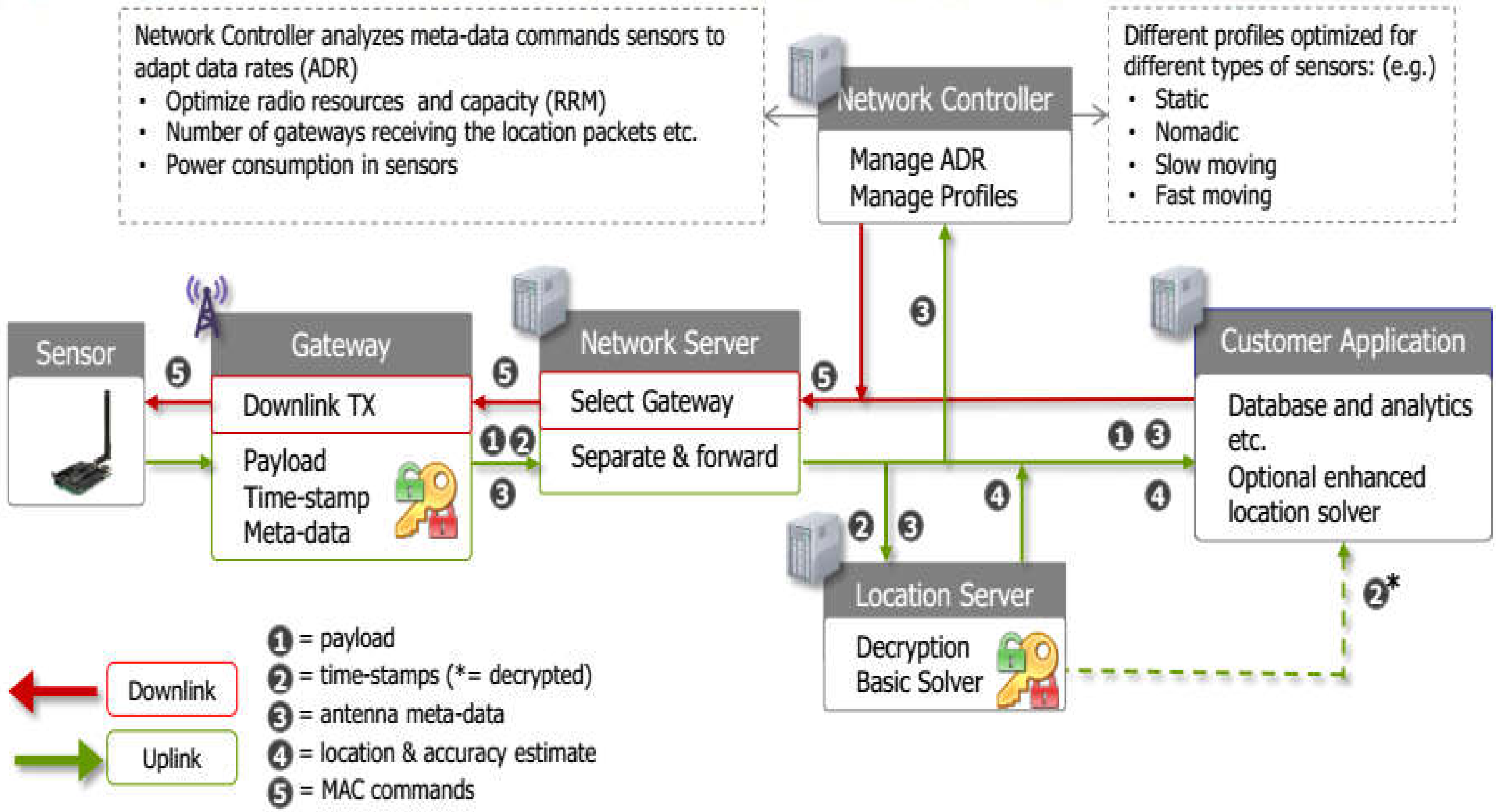


# LoRa System Architecture



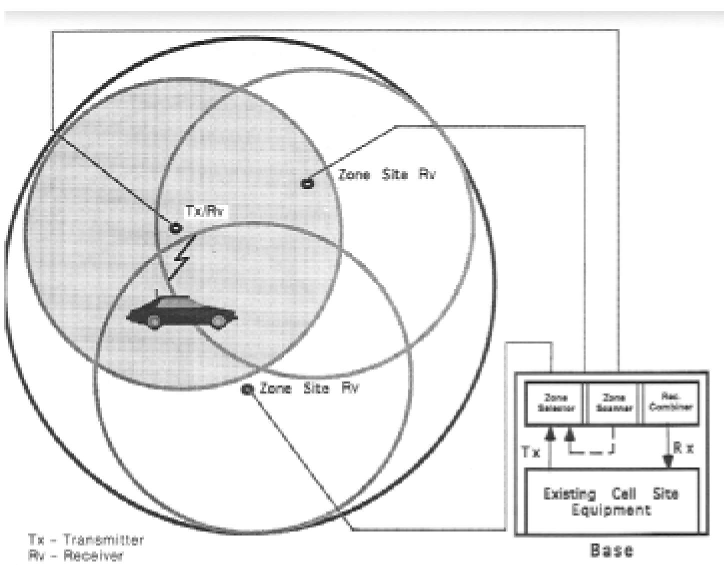
# Geolocation Information Flow

SEMTECH




CAT

# LoRa: RF Resource Management

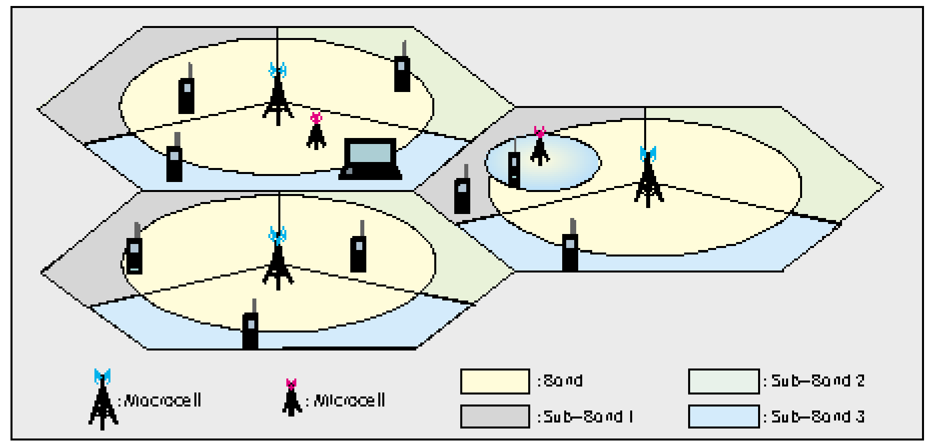
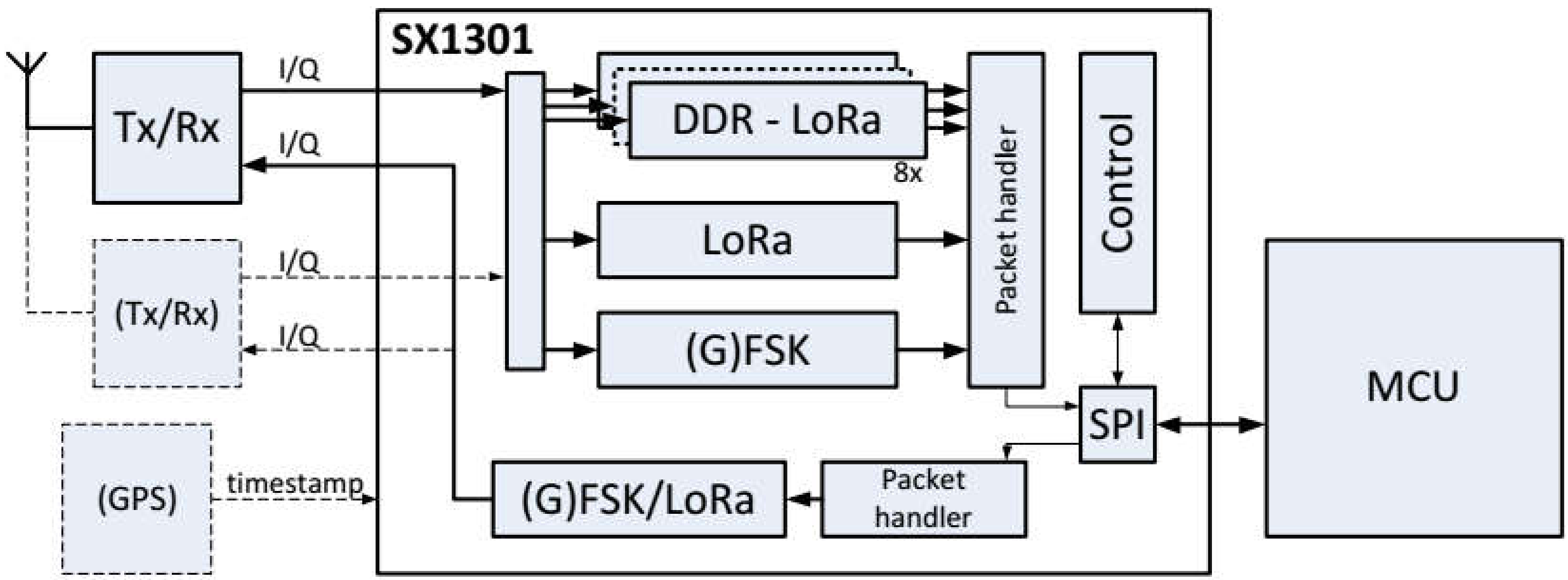
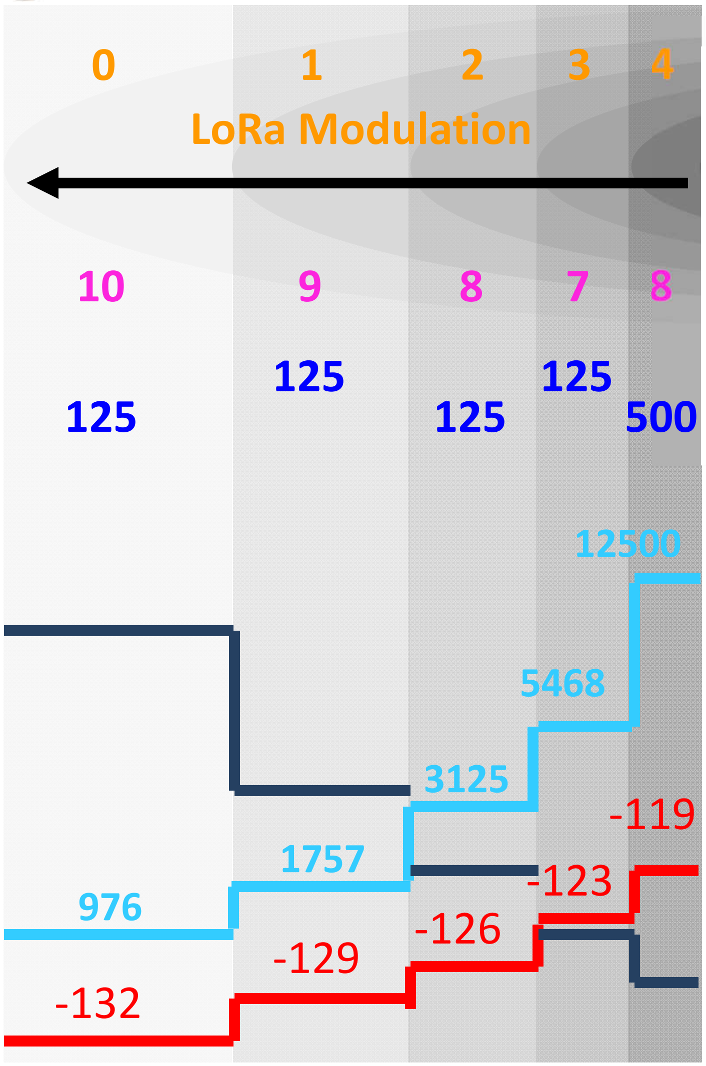




Figure 2. Frequency assignment between multiple cells as well as between macrocells and microcells.


SX1301
Tx/Rx
I/Q
I/Q
(Tx/Rx)
I/Q
I/Q
(GPS)
timestamp
DDR - LoRa
8x
LoRa
(G)FSK
Packet handler
Control
SPI
MCU
(G)FSK/LoRa
Packet
handler

# LoRaWAN™ Network Protocol
## Modulation Settings for USA / FCC




Data Rate (DR)

Range

Spreading Factor (SF)

Bandwidth (BW) (kHz)

Bitrate (BR) (bps)

Receive Sensitivity (dBm)

Time-on-air & consumption

# AS923 ISM Band Channel Frequencies

This section applies to regions where the frequencies [923…923.5MHz] are comprised in the ISM band, which is the case for the following countries:

- Brunei [923-925 MHz]
- Cambodia [923-925 MHz]
- Hong Kong [920-925 MHz]
- Indonesia [923-925 MHz]
- Japan [920-928 MHz]
- Laos [923-925 MHz]
- New Zealand [915-928 MHz]
- Singapore [920-925 MHz]
- Taiwan [922-928 MHz]
- Thailand [920-925 MHz]
- Vietnam [920-925 MHz]


# LoRa Gateways
## (non exhaustive list)


Multi-Tech Conduit

Embedded Planet
EP-M2M-LORA

Ideetron Lorank 8


LinkLabs Symphony


Kerlink IoT Station

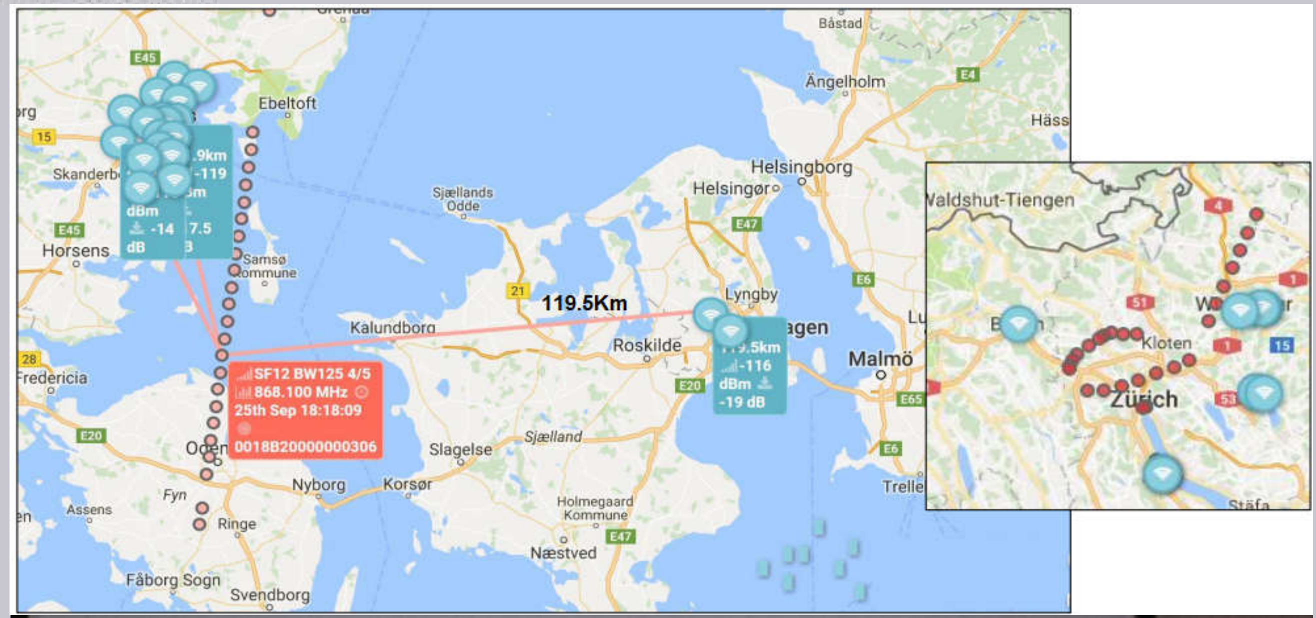
PicoWAN from
Archos

TheThingNetwork

Or build your own one:
Arduino, Rasperry PI, …

# No Limit to What We Can Achieve!





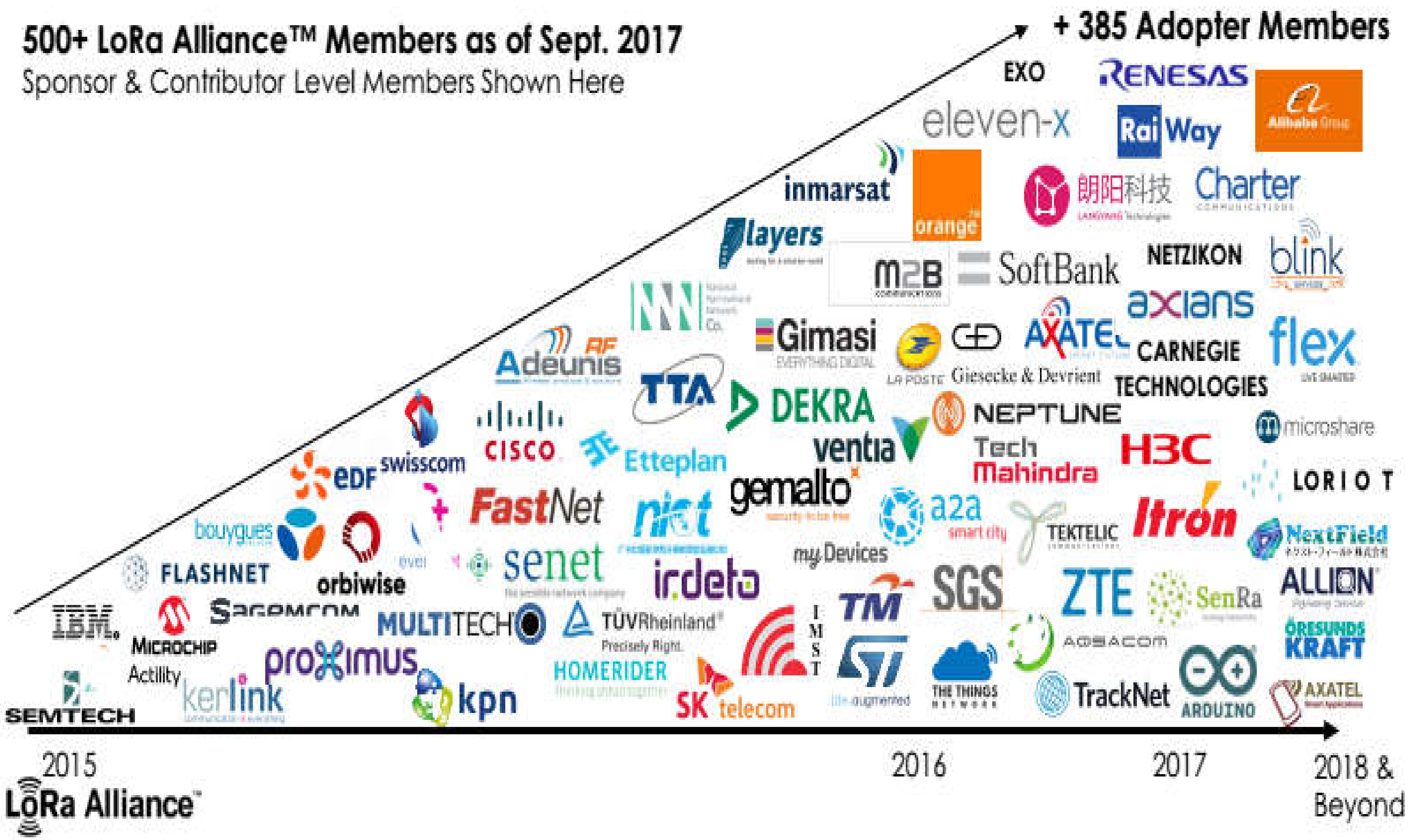
LoRa Alliance

## Fastest-Growing Global Technology Alliance

LoRa Alliance™

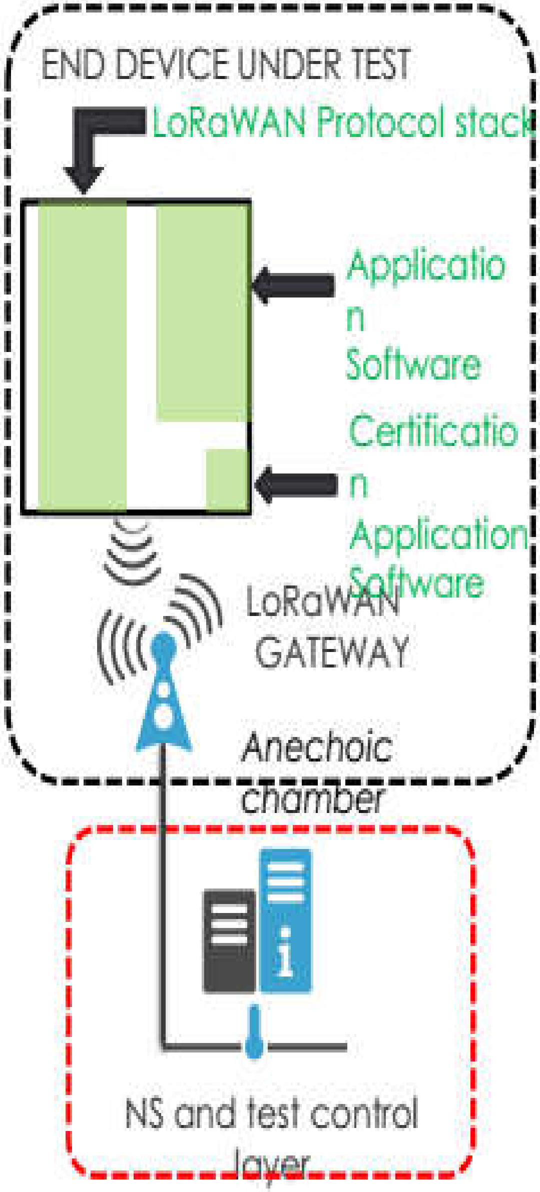
### 500+ LoRa Alliance™ Members as of Sept. 2017

Sponsor & Contributor Level Members Shown Here



# Certification Summary

- Device is certified by version of LoRaWAN
- Device is certified by the region of operation
- Test Requirements defined by Certification Committee
- Test Houses Authorised by the LoRa Alliance
- Device Manufacture decides which ATH to use.
- Successful Certification Results sent to LoRa Alliance from Authorised Test Houses.
- Certification by testing or through Similarity process
- Certified products displayed on LoRa Alliance Website: https://www.lora-alliance.org/certified-products
- For more information on Certification visit: https://www.lora-alliance.org/certification-overview
- Over 70 Devices LoRaWAN Certified



# Worldwide Authorised Test Houses



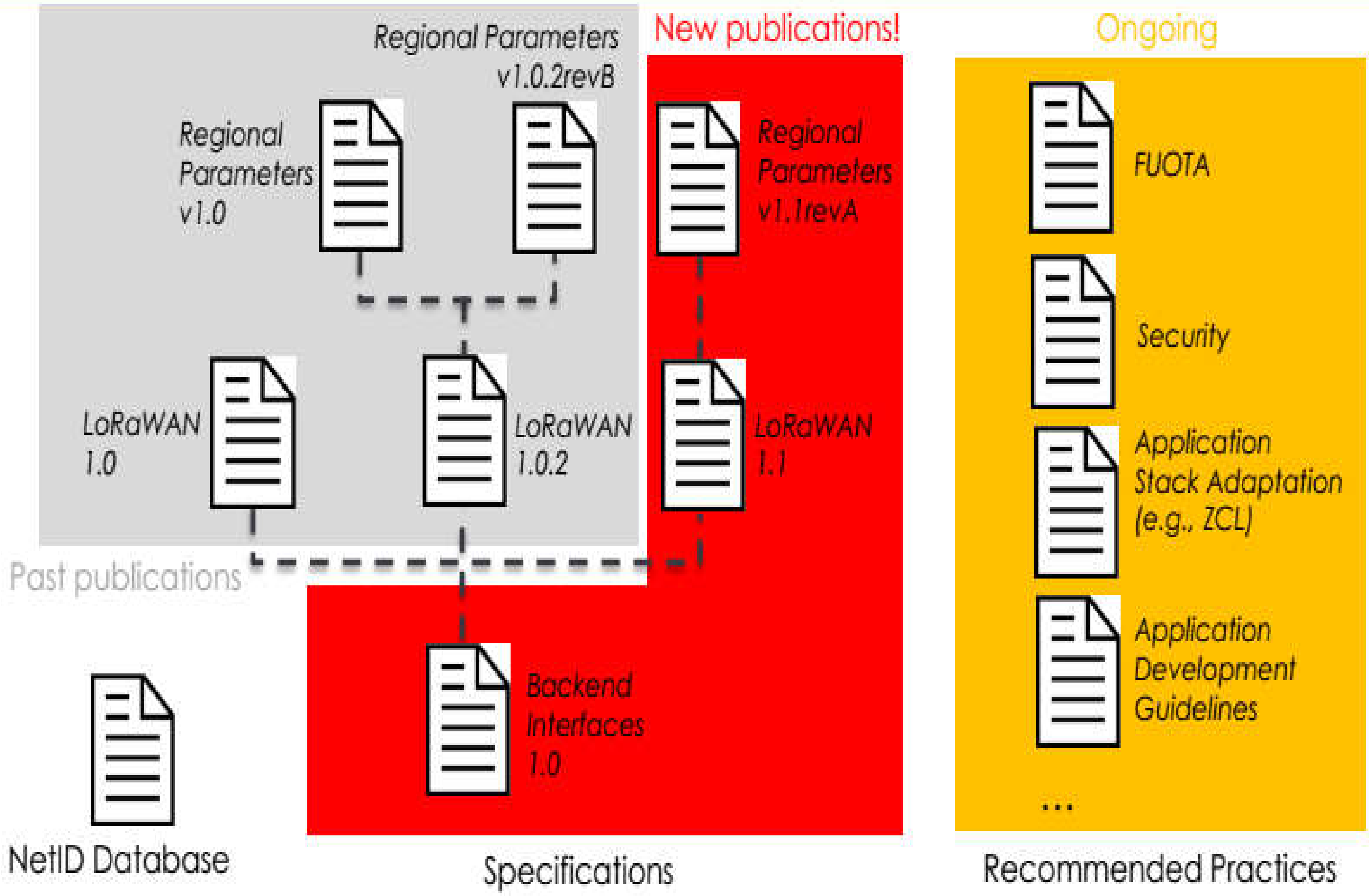
## Worldwide Authorised Test Houses

- 5 Worldwide Authorised Test Houses
- Testing against 4 LoRaWAN regional areas
- With 13 separate locations in Asia (Inc. Japan, Taiwan and Korea), Europe and USA
- New physical Certification locations can be simply added by replication of Certified Test Harness at the new locations.
- LoRaWAN device Radiated RF Performance Evaluation measurement enabled

- For more information join Tech Talk: Certification Deep Dive at 11:30am

# LoRaWAN Certified Products have WORLDWIDE ACCESS

# TC Products


New publications!
Ongoing
Regional Parameters v1.0.2revB
Regional Parameters v1.0
Regional Parameters v1.1revA
FUOTA
Security
LoRaWAN 1.0
LoRaWAN 1.0.2
LoRaWAN 1.1
Application Stack Adaptation (e.g., ZCL)
Past publications
Backend Interfaces 1.0
Application Development Guidelines
...
NetID Database
Specifications
Recommended Practices

LoRa Alliance™

# LoRaWAN™ 1.1 Specification

**Authored by the LoRa Alliance technical committee**

**Chairs**:
N.SORNIN (Semtech), A.YEGIN(Actility)
**Editor**:
N.SORNIN(Semtech)
**Contributors**:
A.BERTOLAUD (Gemalto), J.DELCLEF (ST), V.DELPORT (microchip), P.DUFFY (CISCO), F.DYDUCH (Bouygues Telecom), T.EIRICH (IBM),L.FERREIRA (Orange), S.GHAROUT(orange), O.HERSENT (actility), A.KASTTET(homeriders systems), D.KJENDAL (senetCo), V.KLEBAN (everynet), J.KNAPP (tracknet), T.KRAMP (IBM), M.KUYPER (Tracknet), P.KWOK (Objenious), M.LEGOURIEREC (Sagemcom), C.LEVASSEUR (Bouygues Telecom), M.LUIS (semtech), M.PAULIAC (Gemalto), P.PIETRI (Orbiwise), D.SMITH (multitech), R.SOSS(actility), T.TASHIRO (M2B japan), P.THOMSEN (orbiwise), A.YEGIN (Actility)

**Version**: V1.1
**Date**: 2017 June 28th
**Status:** Final release candidate

# 4 MAC Message Formats

All LoRa uplink and downlink messages carry a PHY payload (**Payload**) starting with a single-octet MAC header (**MHDR**), followed by a MAC payload (**MACPayload**)[1], and ending with a 4-octet message integrity code (**MIC**).

*Radio PHY layer:*

| Preamble | PHDR | PHDR_CRC | PHYPayload | CRC* |
|---|---|---|---|---|

Figure 5: Radio PHY structure (CRC* is only available on uplink messages)

*PHYPayload:*

| MHDR | MACPayload | MIC |
|---|---|---|

Figure 6: PHY payload structure

*MACPayload:*

| FHDR | FPort | FRMPayload |
|---|---|---|

Figure 7: MAC payload structure

*FHDR:*

| DevAddr | FCtrl | FCnt | FOpts |
|---|---|---|---|

Figure 8: Frame header structure

Figure 9: LoRa message format elements

# LoRaWAN™ Backend Interfaces Specification

**Chairs**:
N.SORNIN (Semtech), A.YEGIN(Actility)

**Editor**:
A.YEGIN (Actility)

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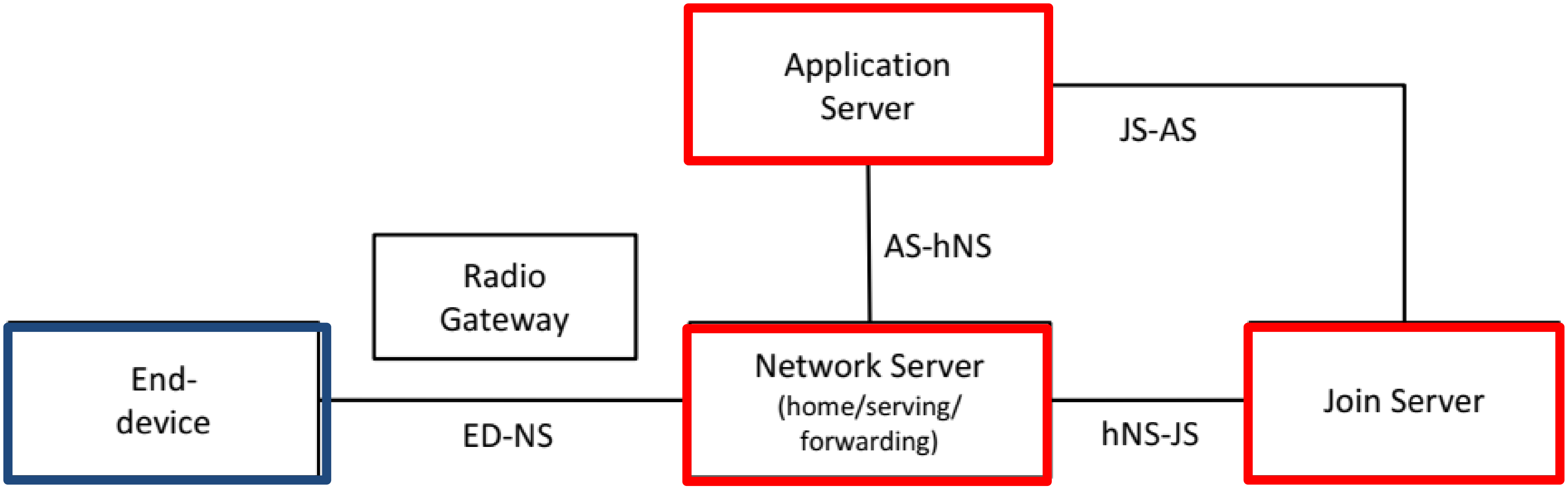
A.BETOLAUD (Gemalto), E.BRUINZEEL (KPN), P.CHRISTIN (Orange), P.DUFFY (Cisco), F.DYDUCH (Bouygues Telecom), J.ERNST (Swisscom), E.FORMET (Orange), O.HERSENT (Actility), D.KJENDAL (Senet), M.KUYPER (TrackNet), M.LEGOURRIEREC (Sagemcom), C.LEVASSEUR (Bouygues Telecom), M.PAULIAC (Gemalto), N.SORNIN (Semtech), P.K.THOMSEN (Orbiwise), A.YEGIN (Actility)

**Version**: 1.0
**Date**: June 30, 2017
**Status:** Final release candidate




**GWMP Protocol**

**LoRaWAN Network Reference Model (NRM), End-Device at home**

hNS-JS: This interface is used for supporting the Join (Activation) Procedure between the JS and the NS.

vNS-JS: This interface is used for Roaming Activation Procedure. It is used to retrieve the NetID of the hNS associated with the End-Device.

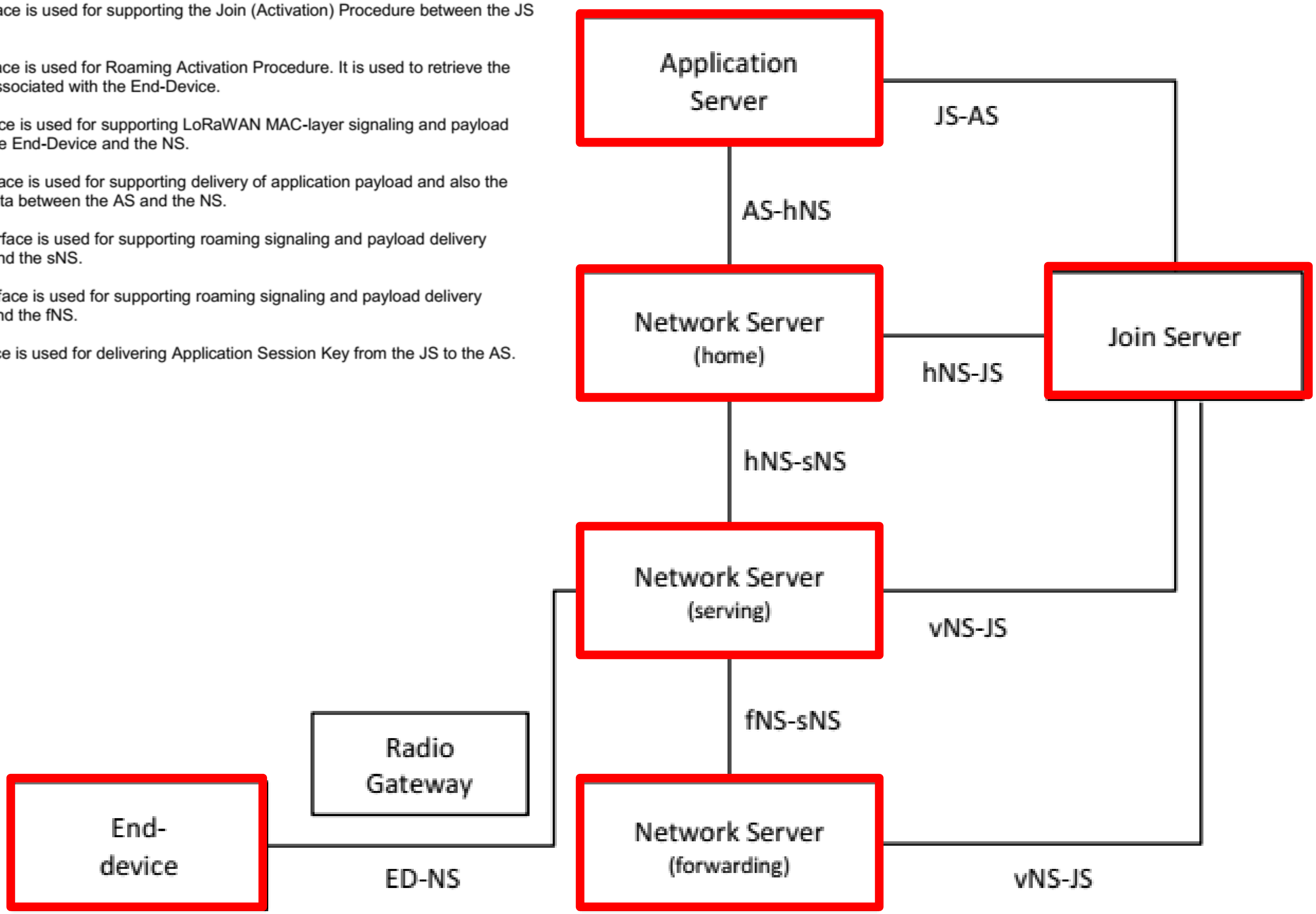
ED-NS: This interface is used for supporting LoRaWAN MAC-layer signaling and payload delivery between the End-Device and the NS.

AS-hNS: This interface is used for supporting delivery of application payload and also the associated meta-data between the AS and the NS.

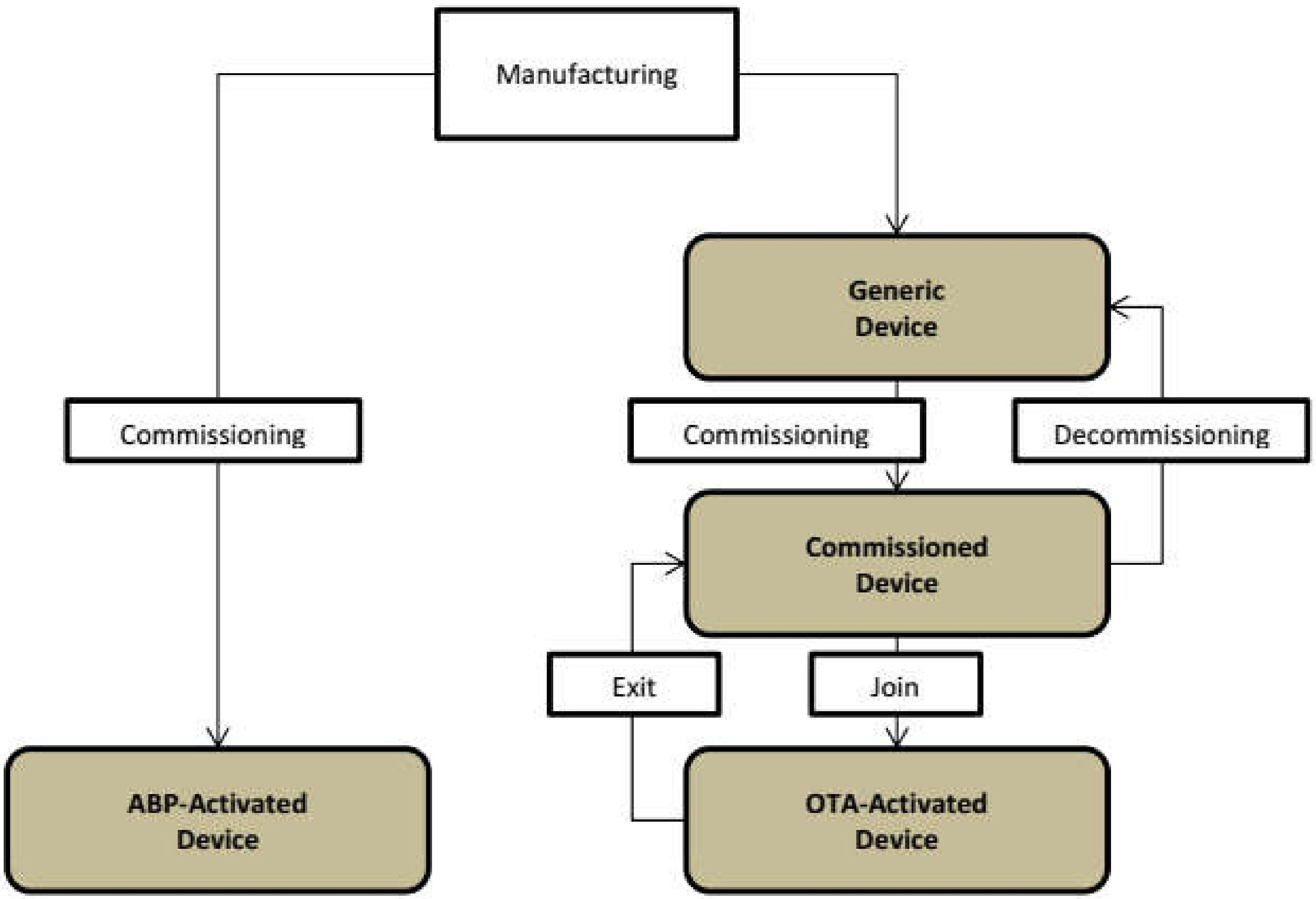
hNS-sNS: This interface is used for supporting roaming signaling and payload delivery between the hNS and the sNS.

sNS-fNS: This interface is used for supporting roaming signaling and payload delivery between the sNS and the fNS.

AS-JS: This interface is used for delivering Application Session Key from the JS to the AS.




**LoRaWAN Network Reference Model (NRM), roaming End-Device**




**End-Device types and states**

**LoRaWAN™ 1.0.2 Regional Parameters**



# NOTICE OF USE AND DISCLOSURE



LoRa Alliance, Inc.
2400 Camino Ramon, Suite 375
San Ramon, CA 94583

# LoRaWAN™ 1.0.2 Regional Parameters

**This document is a companion document to the LoRaWAN 1.0.2 protocol specification**

**Authors**:
LoRa Alliance Technical committee

**Revision**: B
**Date**: 2017 Feb
**Status:** Final

## 2.7 AS923MHz ISM Band

### 2.7.1 AS923 Preamble Format

The following synchronization words should be used:

| Modulation | Sync word | Preamble length |
|---|---|---|
| LORA | 0x34 | 8 symbols |
| GFSK | 0xC194C1 | 5 bytes |

Table 47: AS923 synch words

### 2.7.2 AS923 ISM Band channel frequencies

This section applies to regions where the frequencies [923…923.5MHz] are comprised in the ISM band, which is the case for the following countries:

- Brunei [923-925 MHz]
- Cambodia [923-925 MHz]
- Indonesia [923-925 MHz]
- Japan [920-928 MHz]
- Laos [923-925 MHz]
- New Zealand [915-928 MHz]
- Singapore [920-925 MHz]
- Taiwan [922-928 MHz]
- Thailand [920-925 MHz]
- Vietnam [920-925 MHz]

US008406275B2

(12) **United States Patent**
**Sforza**

(10) **Patent No.: US 8,406,275 B2**
(45) **Date of Patent: Mar. 26, 2013**

(54) **COMMUNICATIONS SYSTEM**

(75) Inventor: **Francois Sforza**, Nice (FR)

(73) Assignee: **Nanoscale Labs**, La Tronche (FR)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 410 days.

(21) Appl. No.: **12/720,139**

(22) Filed: **Mar. 9, 2010**

(65) **Prior Publication Data**

US 2011/0064119 A1 Mar. 17, 2011

(30) **Foreign Application Priority Data**

Jul. 2, 2009 (EP) ..................................... 09305641

(51) **Int. Cl.**
***H04B 1/00*** (2006.01)

(52) **U.S. Cl.** ........................................................ **375/139**

(58) **Field of Classification Search** .................. 375/139, 375/371, 298; 370/441, 307, 516
See application file for complete search history.

(56) **References Cited**

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2008/0309543 A1 * 12/2008 Schaffner ...................... 342/21

FOREIGN PATENT DOCUMENTS

EP 0 952 713 10/1999

OTHER PUBLICATIONS

European Search Report dated Nov. 25, 2009, from corresponding European application.

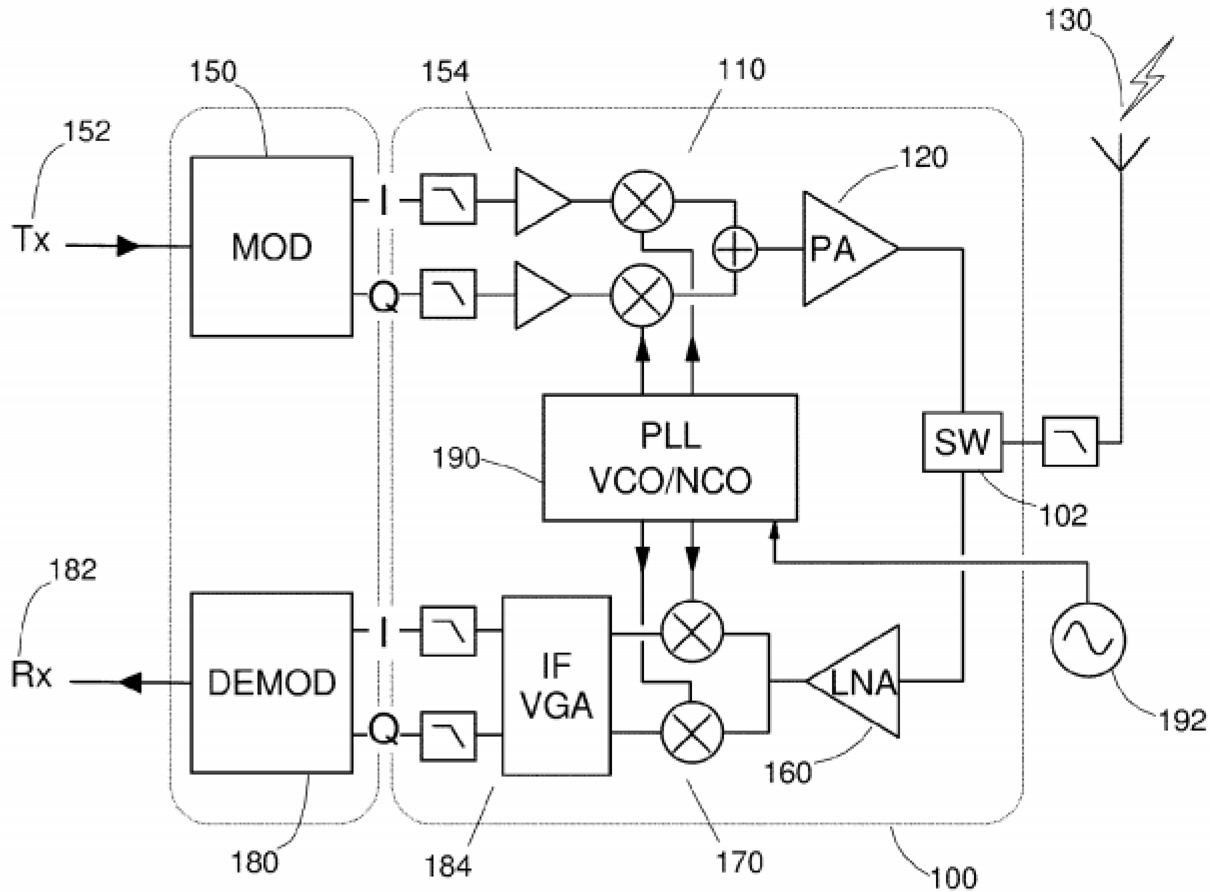
* cited by examiner

*Primary Examiner* — David C. Payne
*Assistant Examiner* — Wednel Cadeau
(74) *Attorney, Agent, or Firm* — Young & Thompson

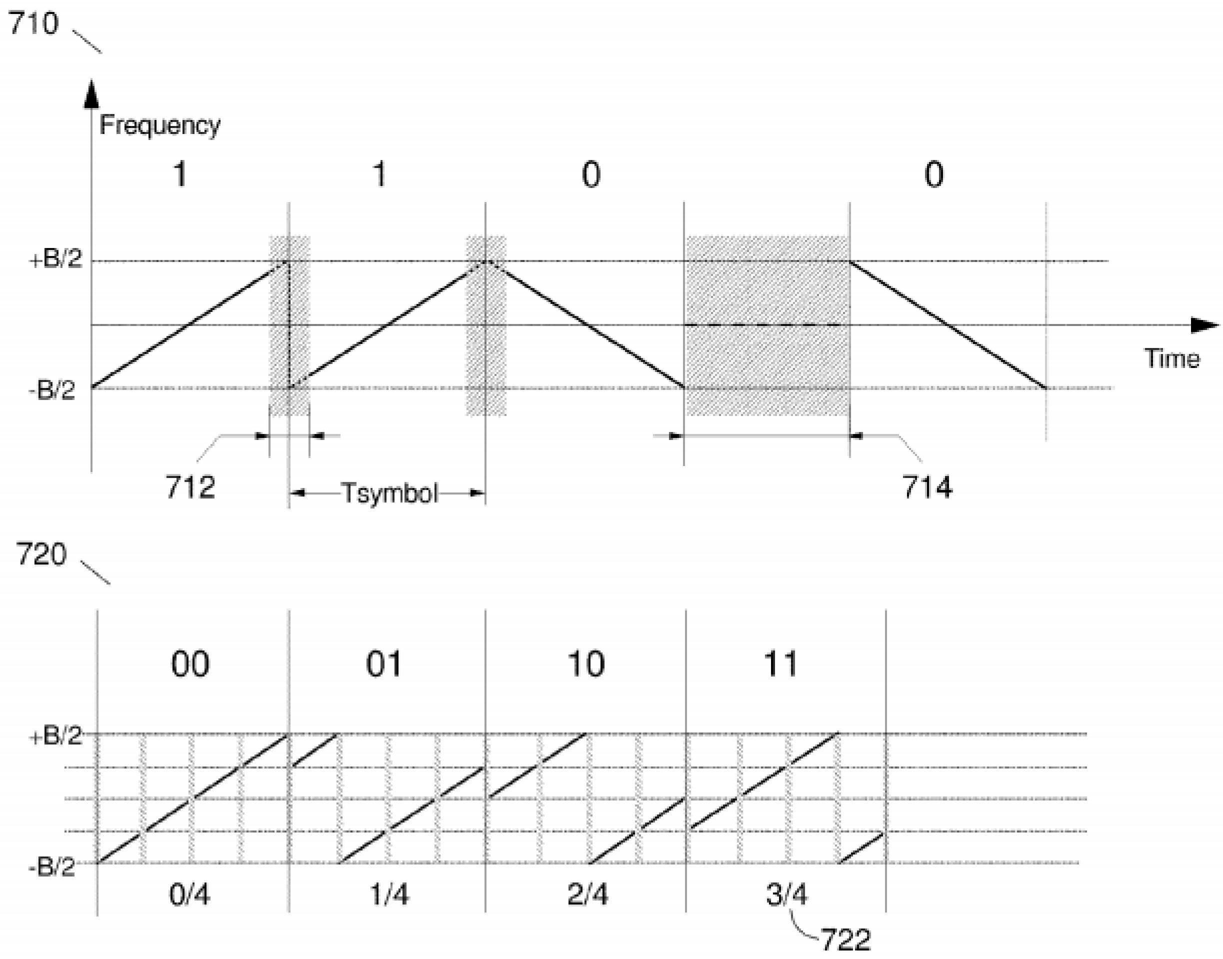
(57) **ABSTRACT**

A communications system includes a modulator for generating a chirp signal aimed at spreading the frequency spectrum of an information signal over a specified spectral bandwidth of a communications channel. The chirp signal has initial and final instantaneous frequency. The chirp signal is controlled from an in-phase control signal and a quadrature-phase control signal to have, in a complex plane, constant amplitude and instantaneous phase. The instantaneous frequency is defined by the speed the instantaneous phase is changed in the complex plane by the in-phase and quadrature-phase control signals; the instantaneous frequency is linearly changed between initial and instantaneous frequencies over the whole duration of the chirp signal; the initial and final instantaneous phases of the chirp signal are identical. The communications system also described an adapted demodulator capable of working even in presence of a significant frequency and/or timing offset between the transmitting and receiving clocking systems.

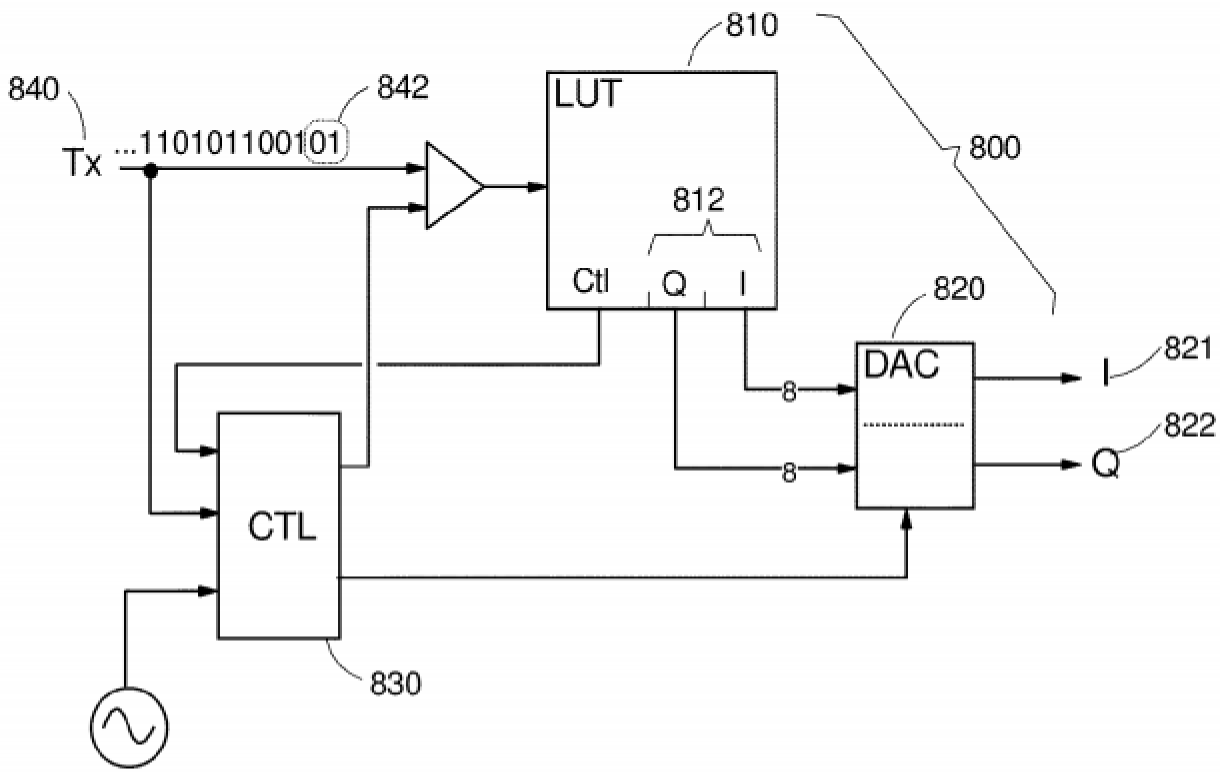
**20 Claims, 11 Drawing Sheets**



130
150
154
110
152
120
Tx
MOD
I
Q
PA
PLL
VCO/NCO
SW
190
102
182
Rx
DEMOD
I
Q
IF
VGA
LNA
192
160
180
184
170
100

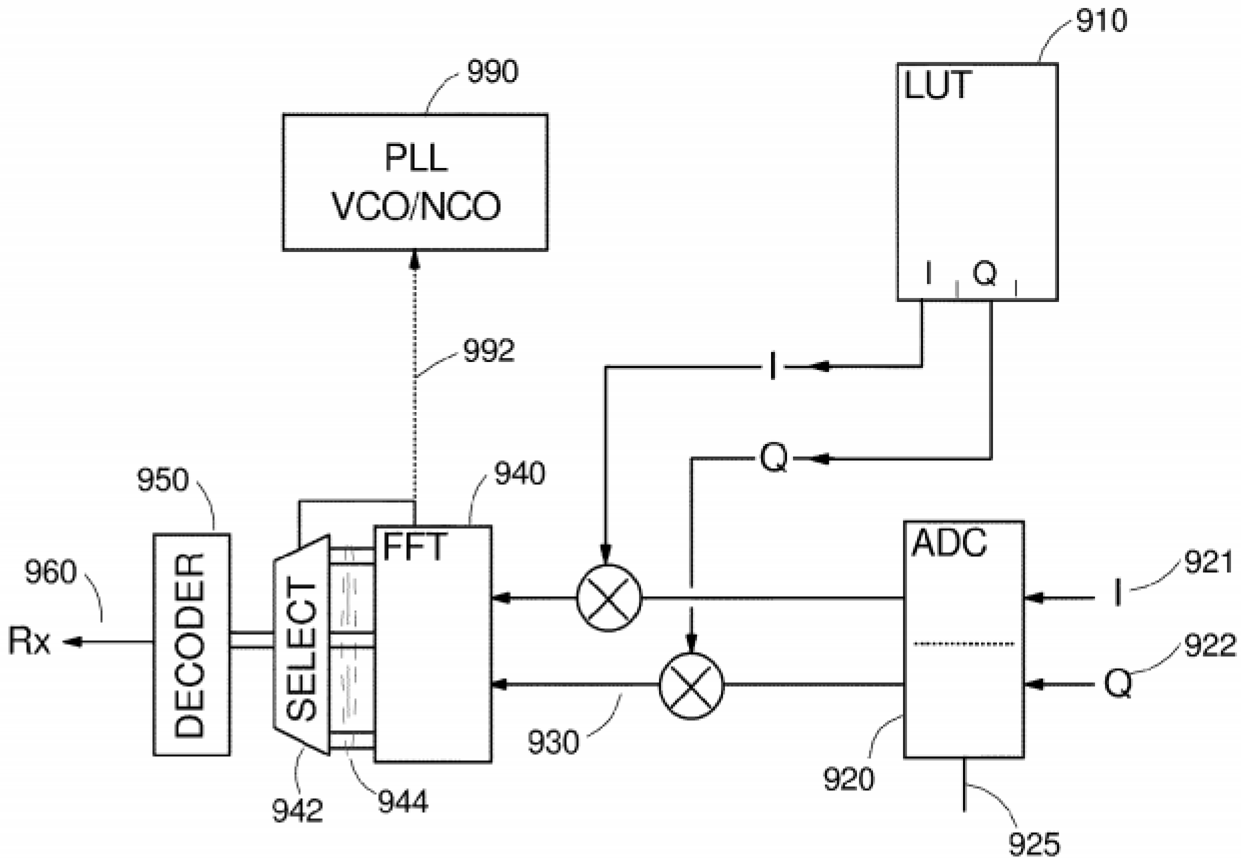


710
Frequency
1
1
0
0
+B/2
-B/2
Time
712
Tsymbol
714
720
00
01
10
11
+B/2
-B/2
0/4
1/4
2/4
3/4
722



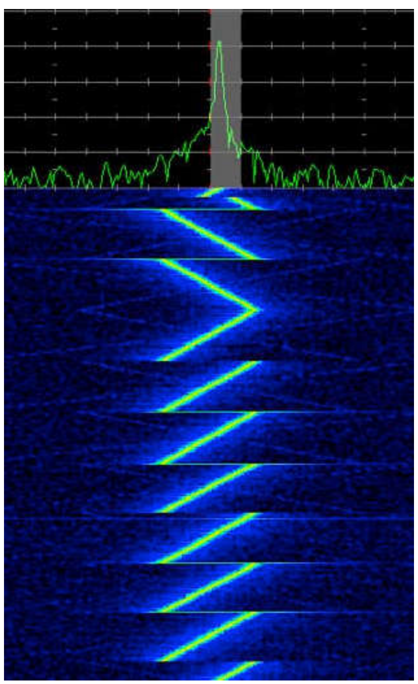
810
800
840
842
Tx
...1101011100101
LUT
812
Ctl
Q
I
820
DAC
821
I
822
Q
8
8
CTL
830

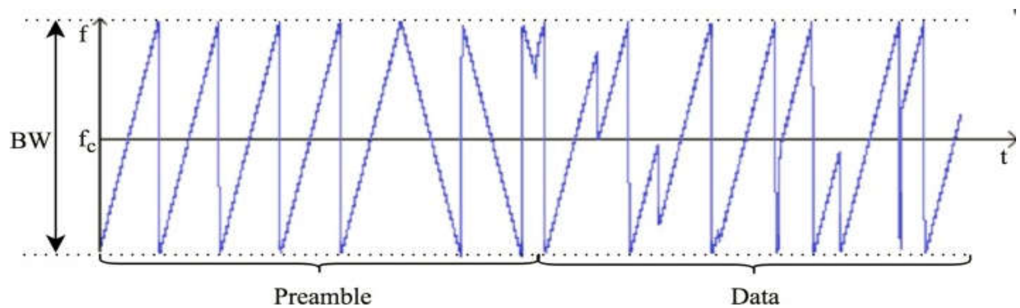

Figure 8

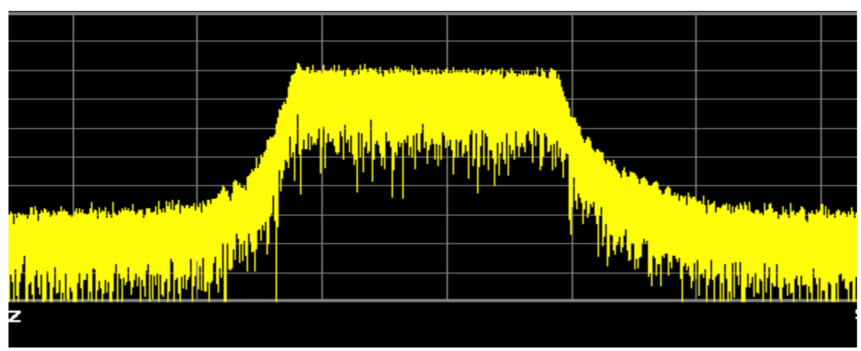

990
PLL
VCO/NCO
992
910
LUT
I
Q
I
Q
950
940
960
DECODER
SELECT
FFT
ADC
921
I
922
Q
Rx
930
920
942
944
925

# LoRaWAN™ Network Protocol
# LoRa® Technology Modulation

- A Spread Spectrum Technology
  - Developed by Semtech Corporation ([http://www.semtech.com/](http://www.semtech.com/))
  - Chirped-FM modulation, symbols of ramping frequency
  - Processing gain = increased receive sensitivity
  - Enables longer range at expense of lower data rate






The End