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Time in Internet of Things….

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Confession……..

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I was late in sending my picture & bio for the conference website….

So Pat & Marc threatened to put a picture of “Gluten free Vegan Pizza”….

…… …… …… …… …… ……. With no Cheese or Tomatoes & only veggies.

Repentance…

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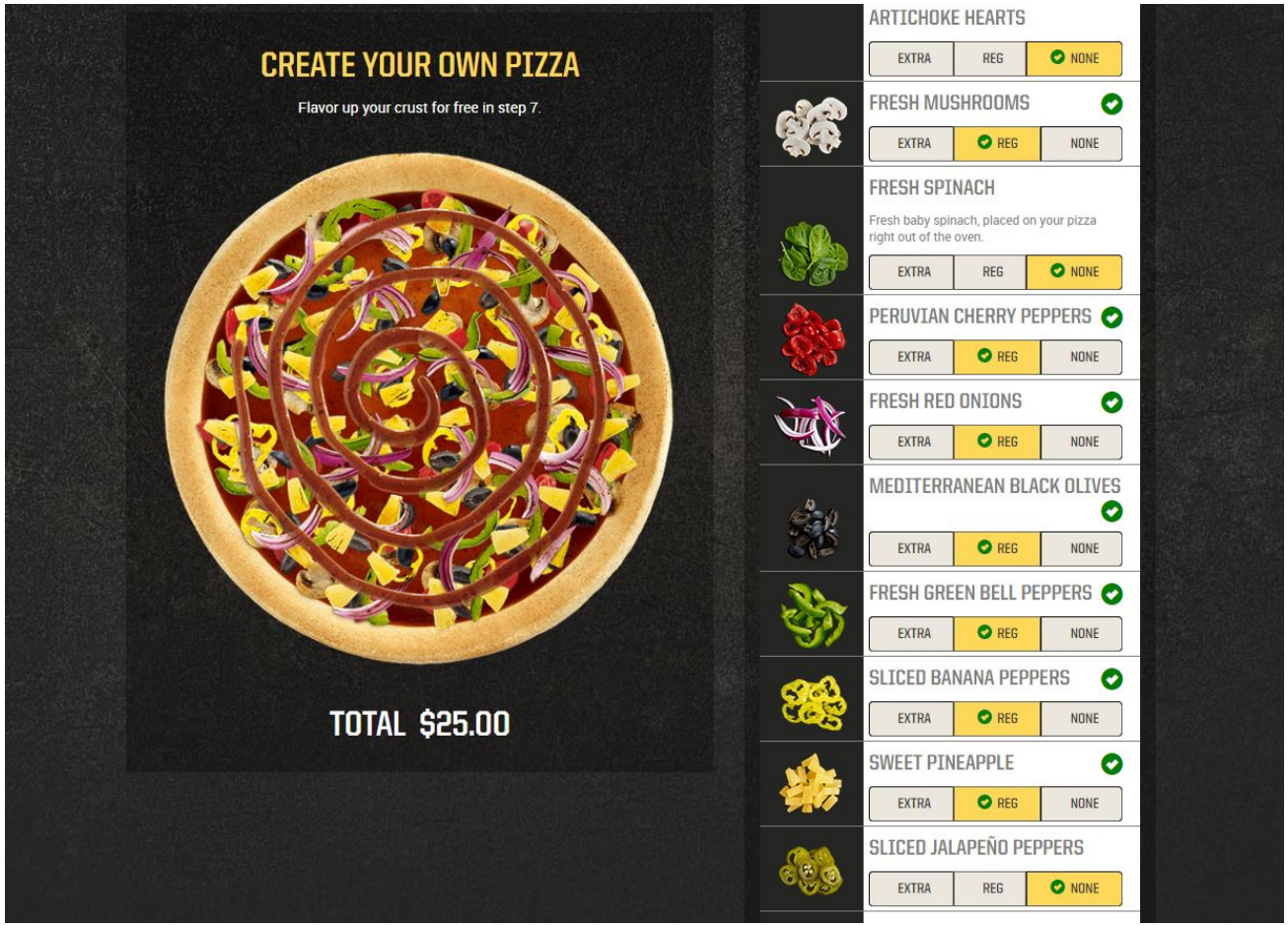
This is how I might have been on the website……



Repentance…

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OR given my roots..

Uthappam- A thick, spongy rice pancake with lots of veggies & peppers

AGENDA

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- What is Internet of Things
  - IOT and IIOT
  - Brief Comparison
- Structure/Anatomy of (I)IOT networks
- Examples of IIOT applications
- Precision requirements of transferred time
- Protocols for time transfer for IOT/IIOT
- Challenges/Constrains in TT for IoT
- Comparison of TT protocols
- The enabling technologies/ gaps
- Conclusion & Closing thoughts

What is IoT ?

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There are many definitions floating around the Cyberspace

The Definition I like

"The Internet of Things (IoT) is a system of "networked"- interrelated computing devices, machines, objects, people (or animals) that are provided with unique identifiers and the ability to transfer data without requiring human-to-human or human-to-computer interaction."

Further IOT systems can be behaviorally segmented into

- Consumer (or Human) IoT - HIoT
- Industrial IoT –IIoT

An interesting discussion on this classification can be found at

http://www.moorinsightsstrategy.com/wp-content/uploads/2013/10/Behaviorally-Segmenting-the-IoT-by-Moor-Insights-Strategy.pdf

Anatomy of IoT network

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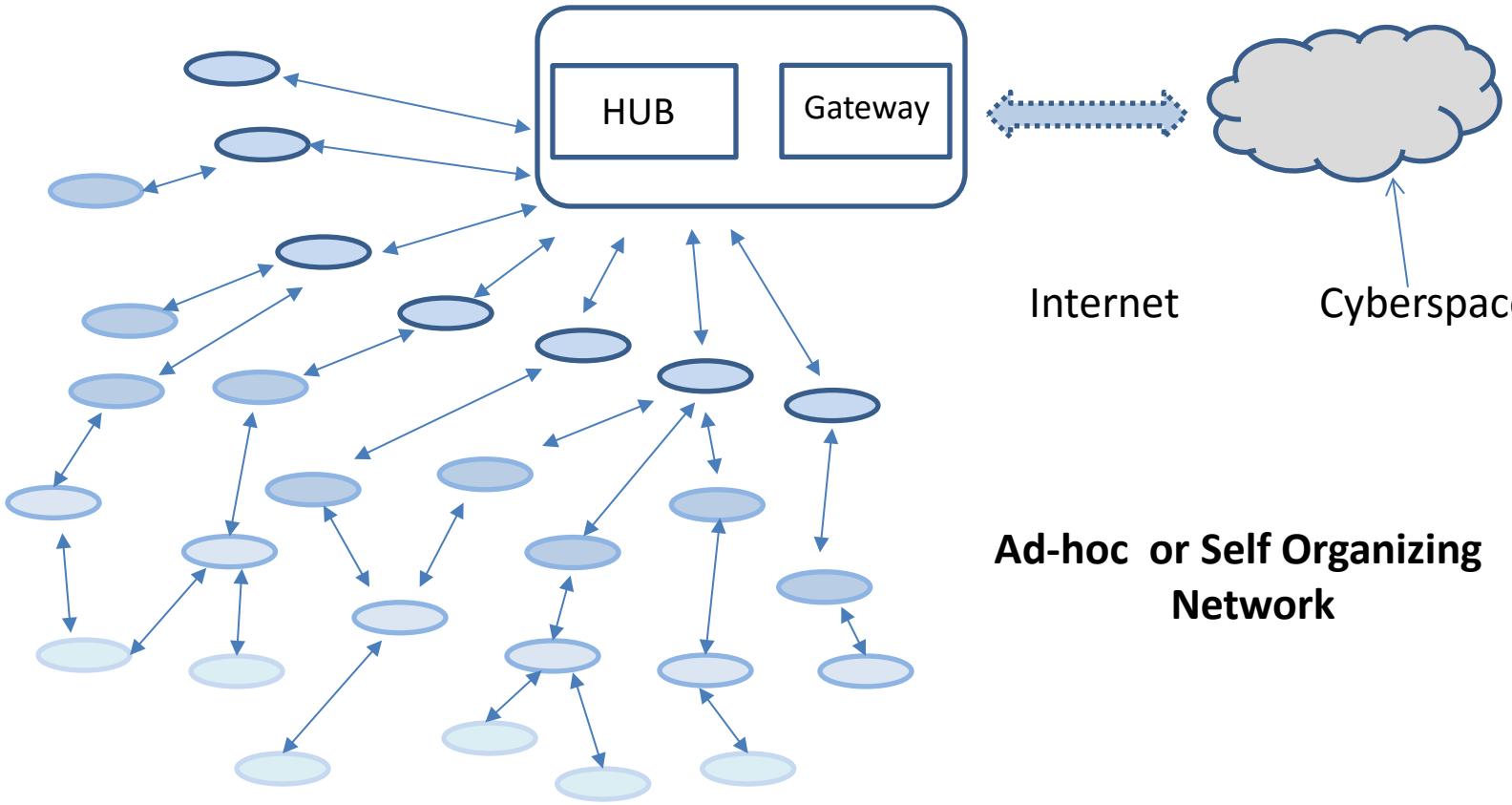
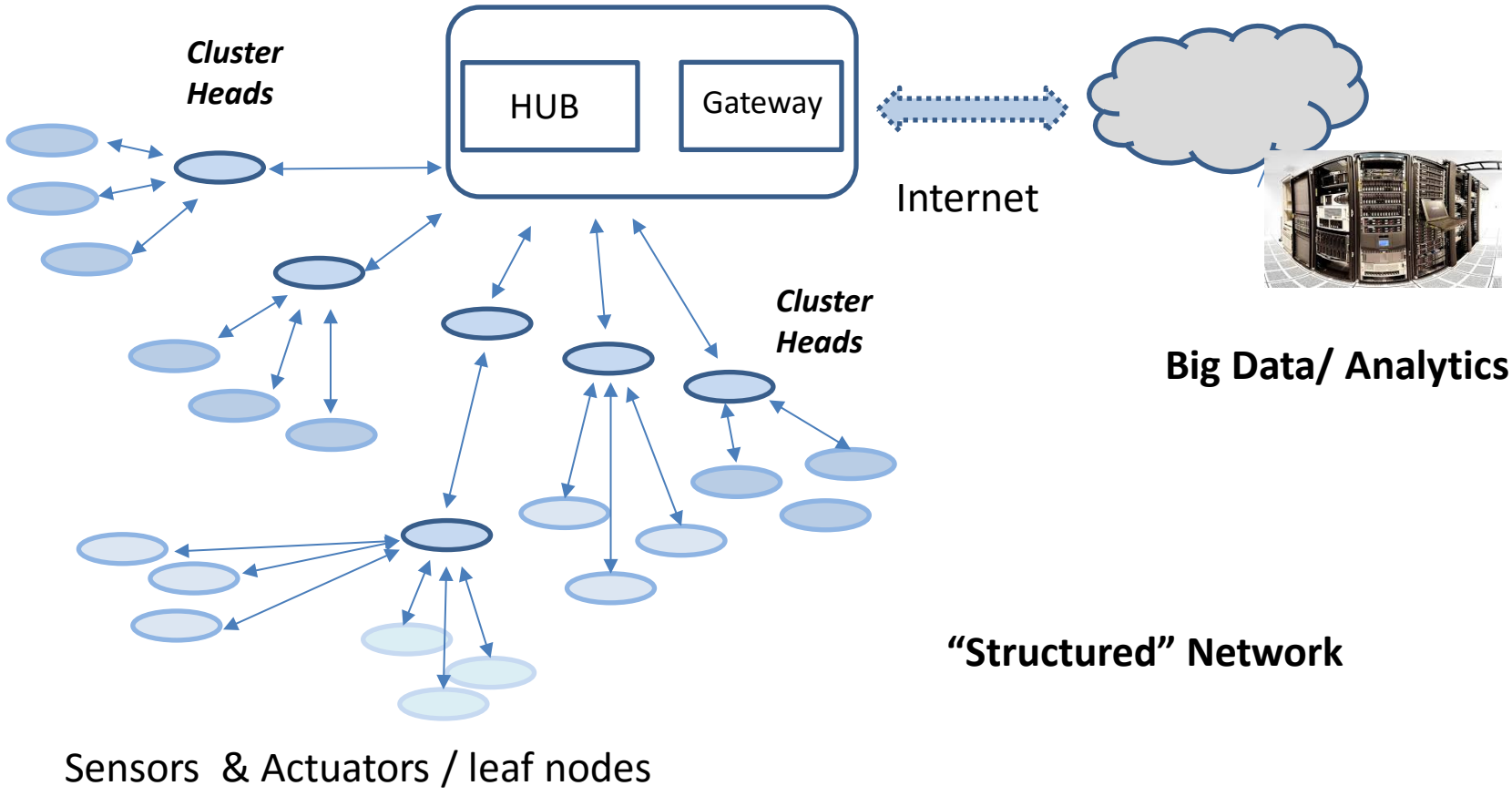


Anatomy of IoT network -II



HIoT vs IIoT

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Attribute	IIoT	CIoT/HIoT
Availability	0.99999 (5 '9's)	0.99 to 0.999 (2 or 3 '9's)
Product lifecycle	Long-(until obsolete)	Whims of Style/budget
Human Interaction	Autonomous	Reactive
Response to failure	Resilient, fail in place	Replace
Network Access	Generally persistent	Persistent/ intermittent /interrupted
Network topology	unstructured	Structured
Switching Costs	low	high

Examples of HIoT applications

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- Examples of HIoT / CIoT
  - Smart watches
  - Exercise tracking
  - IP based entertainment systems
  - Smart Appliances / White goods (Refrigerators etc.)
  - Residential HVAC

Examples of IIoT applications

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- Examples of IIoT
  - Robotics
  - Structural Integrity monitoring (Mech Stress)
  - Industrial HVAC
  - Active , IP based Security Systems
  - Fleet Tracking Systems
  - Professional Medical Systems

Look & Feel:
Highly distributed “Supervisory, Control & Data Acquisition Systems”

Impact of IIoT (& Analytics)

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Changing the business model

From selling "a" product ……TO:

Offering Product-Service Hybrids

(Reactive → Proactive)

Was	Is/ Shall be	New Services
Jet Engines / Scheduled Maintenance	Sensor Equipped Engines/ Predictive Maintenance	+ Fleet optimization services
Tires	Tires with sensors/ Tires as a Service	Fuel Consumption Reduction Service
Farm Equipment	Farm Equipment with Sensors/ remote diagnostics & optimization	Agricultural information services

What about time?

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So what has “time” got to do….

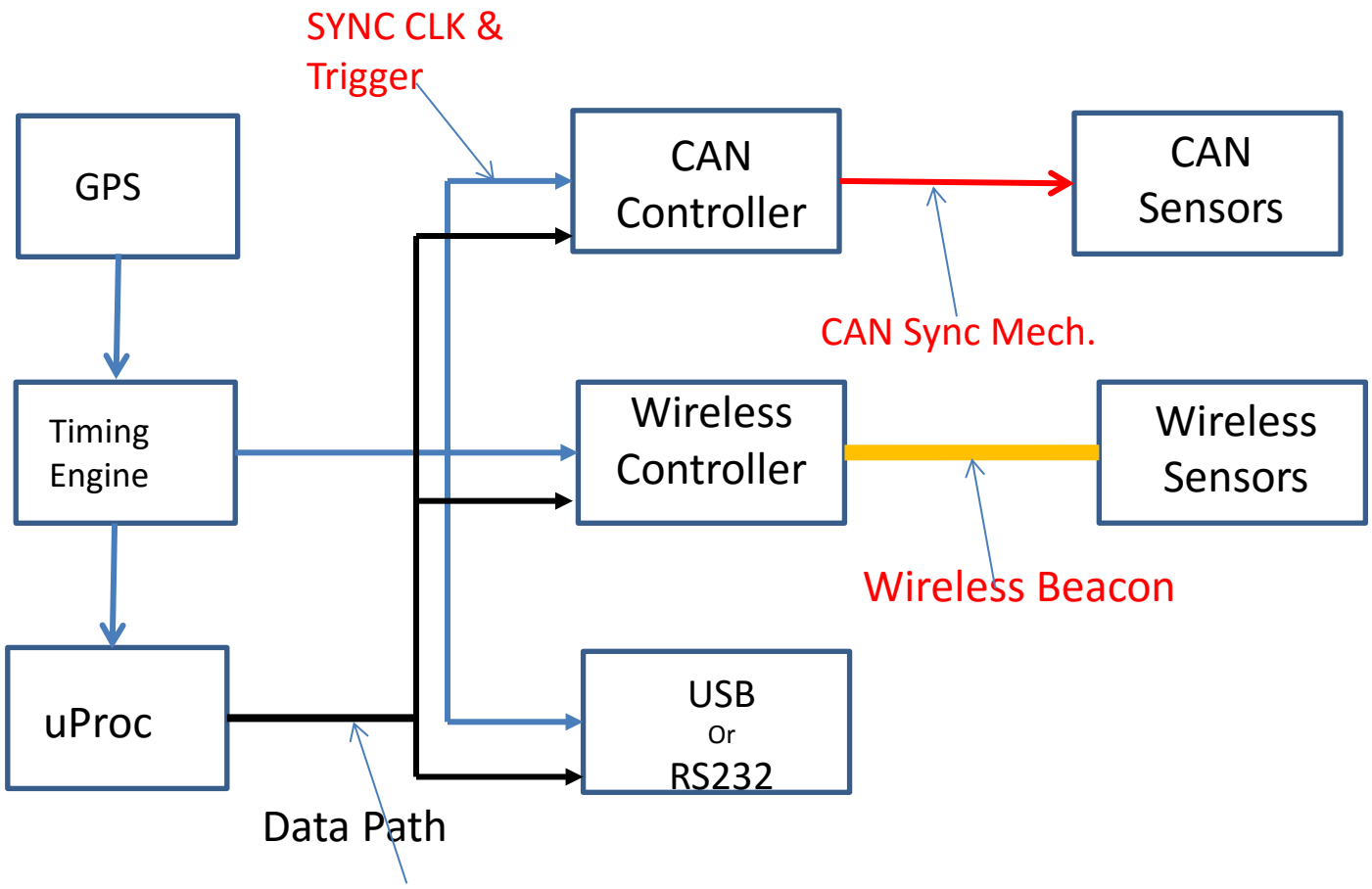
Common time forms the basis for

- Data diffusion
- Temporal co-relation of data
- Motion detection, Velocity estimation
- Security (limited use of keys, detection of replay attacks)
- Data consistency
- Concurrency control
- Medium Access control & duty cycling
- Localization(e.g. based on time of flight measurement techniques)

Example* Structural Health Monitoring and Reporting System

* Based on Arms et al.: "*Synchronized System for Wireless Sensing, RFID, Data Aggregation, & Remote Reporting*", *AHS forum 65, Grapevine, TX, 2009*

Timing Architecture of SHMR



Precision Requirements

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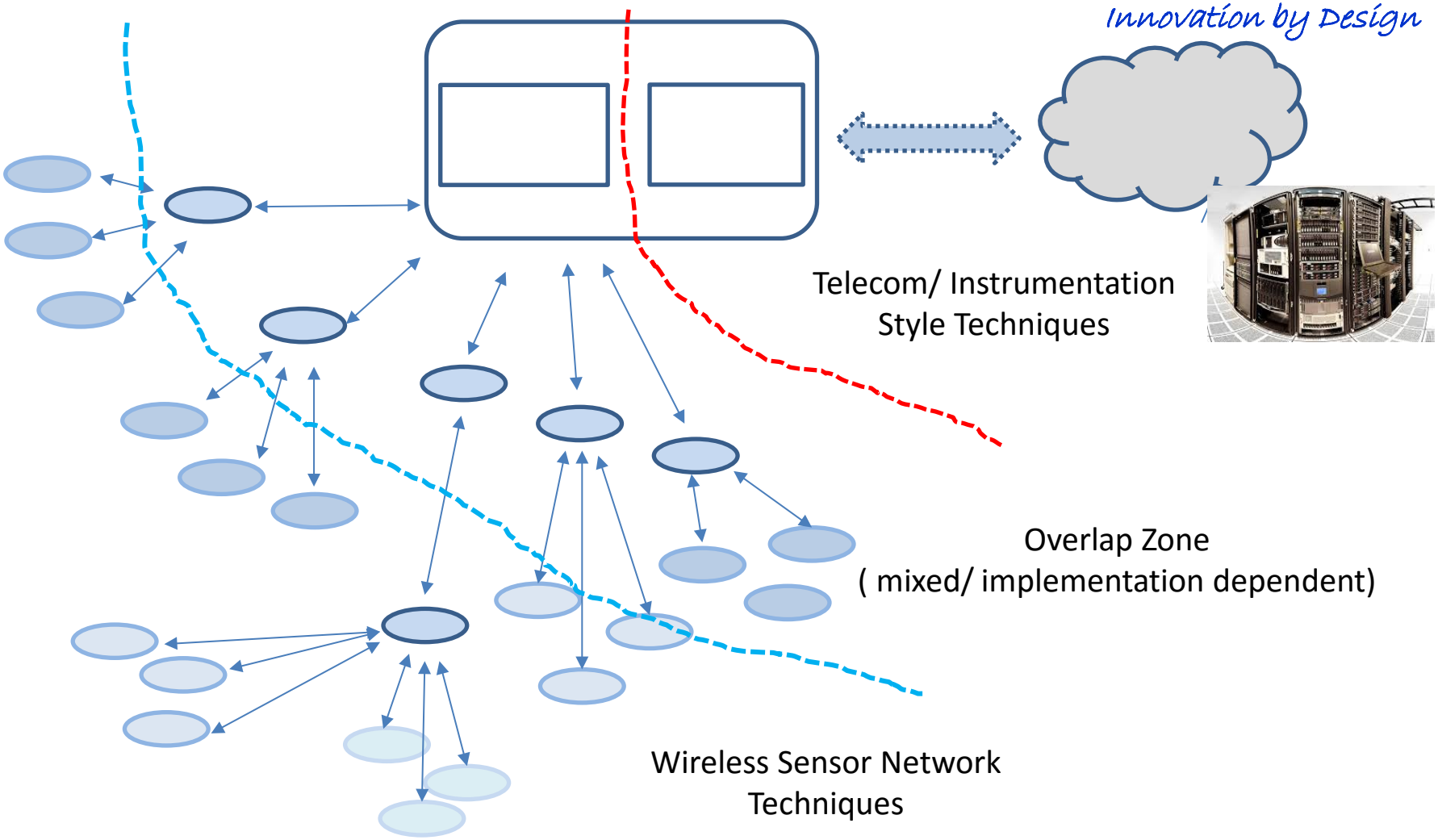
It depends on the Application…
In above example

Frequency -: +/- 3PPM (targeted)
Time/ Phase accuracy : 5uS

Electrical Engineer's may remember the "Nyquist Criterion"

Application	Precision Needed	Remarks
Ranging	< 50 uS	e.g. Determining angle of arrival of sound waves
TDMA	50 – 100+ uS	Can increase quickly as number of nodes on a network increase
Fast Physical Systems	< 1mS	e.g. Measurement on Engines/ Turbines
Medium Physical systems	10-500 mS	e.g. Sensors in Automotive applications
Slow Physical systems	1 sec+	Environmental sensors

Time Distribution Protocols



Time Distribution Protocols

- Telecom/ Instrumentation style
  - PTP (IEEE-1588), NTP……..
- Wireless Sensor N/W style
  - RBS- Reference broadcast synchronization
  - LTS-Lightweight Tree Based Synchronization
  - TPSN-Timing-sync Protocol for Senor Networks
  - FTSP-Flooding Time Synchronization Protocol
  - TDSP- Time Diffusion Synchronization Protocol
  - Mini-Sync
  - Tiny-Sync

Challenges/ Constraints

Major Challenges

- Limited Energy
- Cost
  - Bandwidth limitations
  - Unstable network conditions
  - Limited Hardware capabilities
- Tightly coupled to the target environment
  - Robustness (requirement)
  - Non determinism due to deployment conditions
  - Often retrofitted on to original product.

Time Dist. Prot.- Comparison

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Protocol/ Author(s)	Accuracy	Energy Efficiency	Complexity	Scalability	Fault Tolerance
RBS	High	High	High	Good	No
Romer's	Low	High	Low	Poor	No
Mock et. al	High	Low	High	-	Yes
Ganeriwal et.al	High	Avg	Low	Good	Yes
Sichitiu & Veerarittiphan	High	High	Low	-	Yes
Time Diffusion Protocol	High	Avg	High	Good	Yes

Based on : Clock Synchronization for W S Ns: A Survey-Sundararaman et.al (UOI, Chicago)

Enabling Technologies (Wish list)

- Ultra low power technologies
  - ❖Semiconductor
  - ❖MEMs
- Deep sleep capabilities
  - ❖Low wake up times
- Cheap Clock sources
  - ❖ Tighter bounds on stability

Concluding Thoughts

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- IoT along with Data Analytics presents new opportunities
- The technologies & techniques that enable IIoT applications rely on availability of common time
- However the accuracy & precision needed is varied & application dependent

Questions

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Questions?

Thank you for your attention

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