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Never Stand Still

Advances in Internet of Things and Cyber Physical Systems and its Adoption to Smart Ship

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The University of New South Wales
Australian Defence Force Academy

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2. **Top 5 Issues – IoT and CPS Adoption**
3. **IoT and CPS Solutions – Effort to date**
4. **Smart Adoption – The Success Evidence**
5. **Smart Ship – Top 10 Challenges**
6. **Smart Ship Solution – Embrace new Technology**

Conclusion

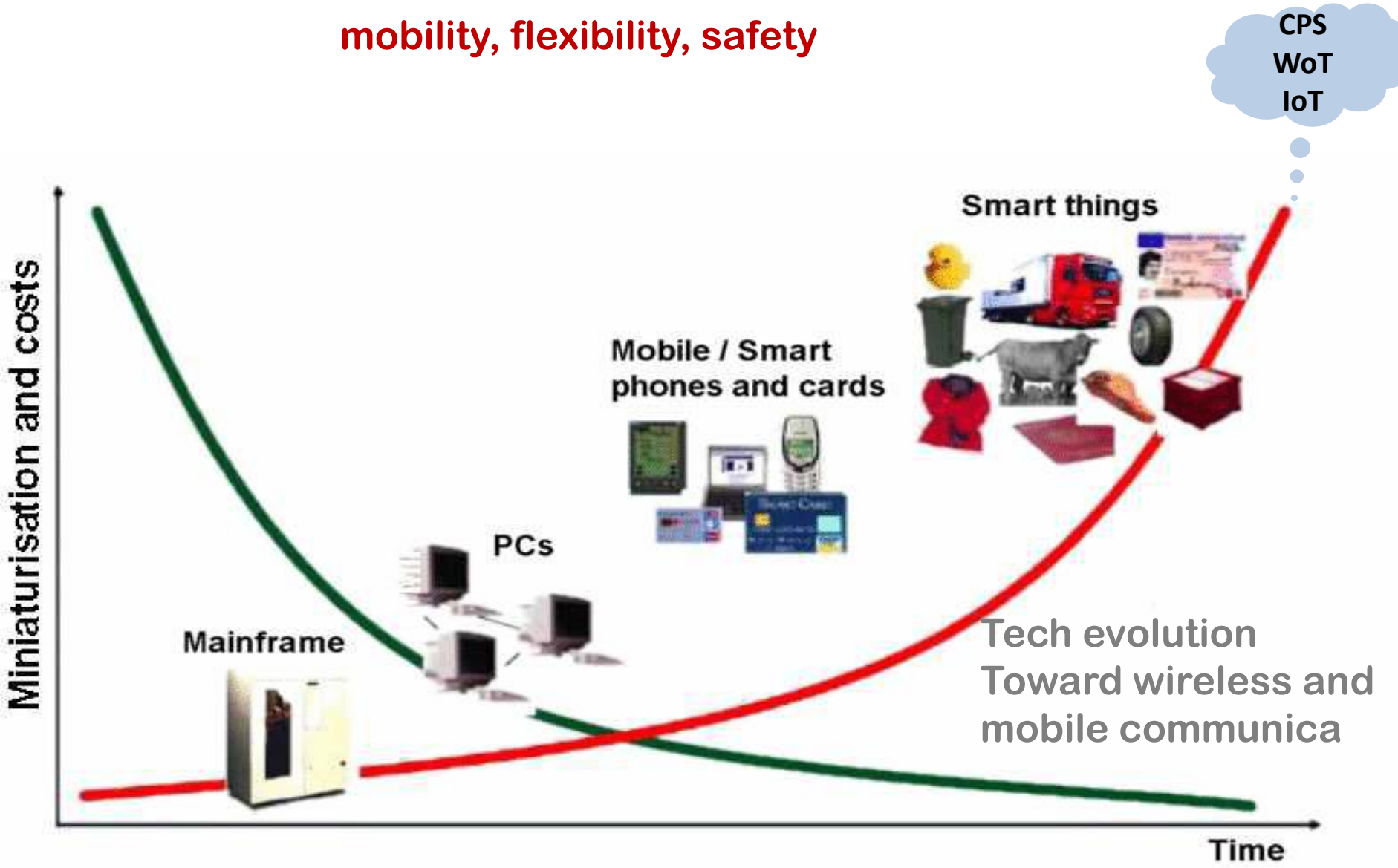
1. IoT and CPS

- New Industrial Frontier

New Industrial Frontier
– IoT, WoT and CPS

Clouds
Internet of Things
Web of Things
Cyber Physical Systems

mobility, flexibility, safety

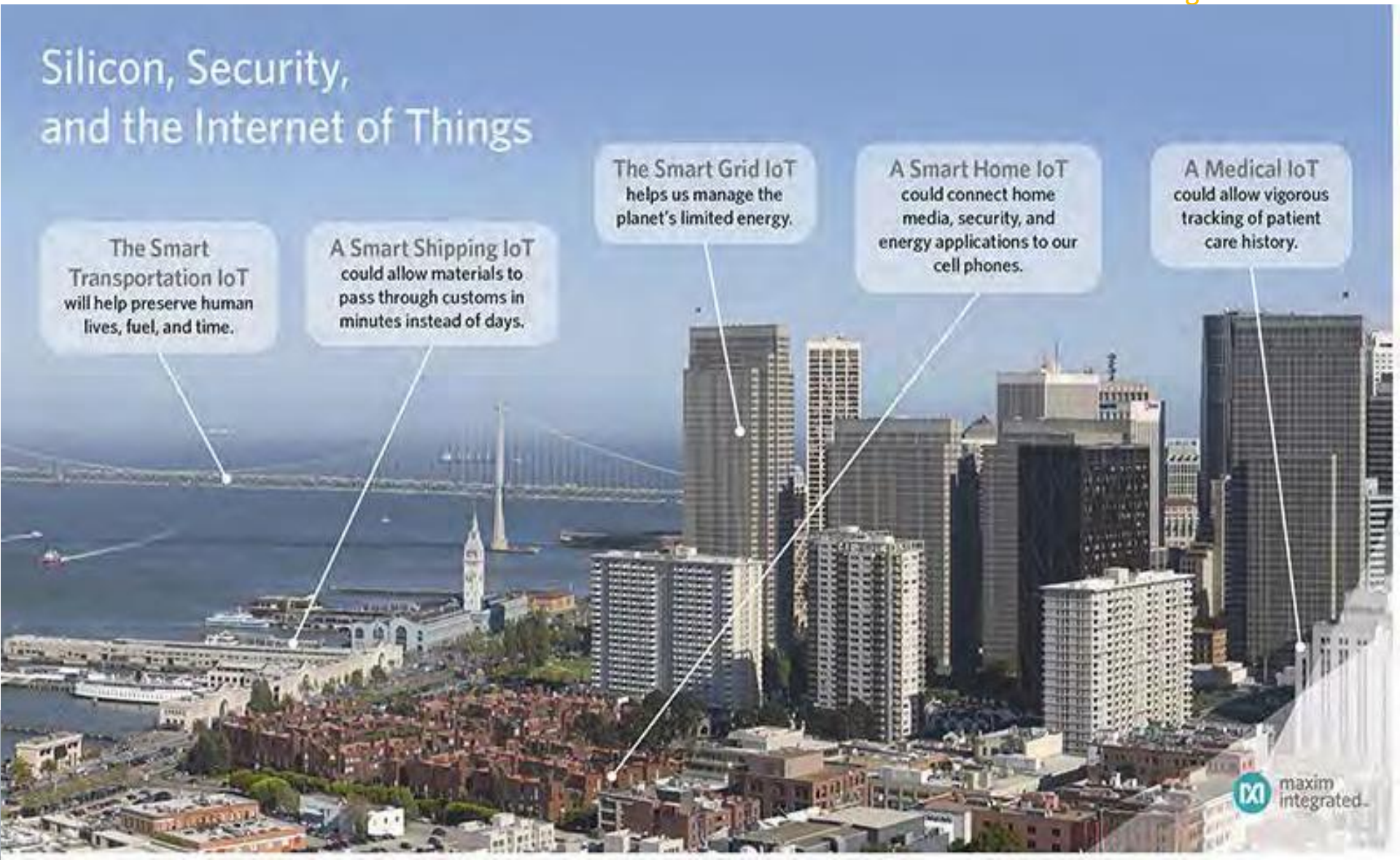


IoT - Examples

- The **Internet of Things** (**IoT**, also **Cloud of Things** or **CoT**) refers to the interconnection of uniquely identifiable embedded computing like devices within the existing Internet infrastructure.
  Example: Smart Grid
- Networks of functional tightly coupled system
- the Internet of Things is primarily focusing on using various technologies such as RFID, Zigbee, Bluetooth or 6LoWPAN.
- Things, in the IoT, can refer to a wide variety of devices such as heart monitoring implants, biochip transponders on farm animals, automobiles with built-in sensors, or field operation devices.

IoT - Tightly coupled system

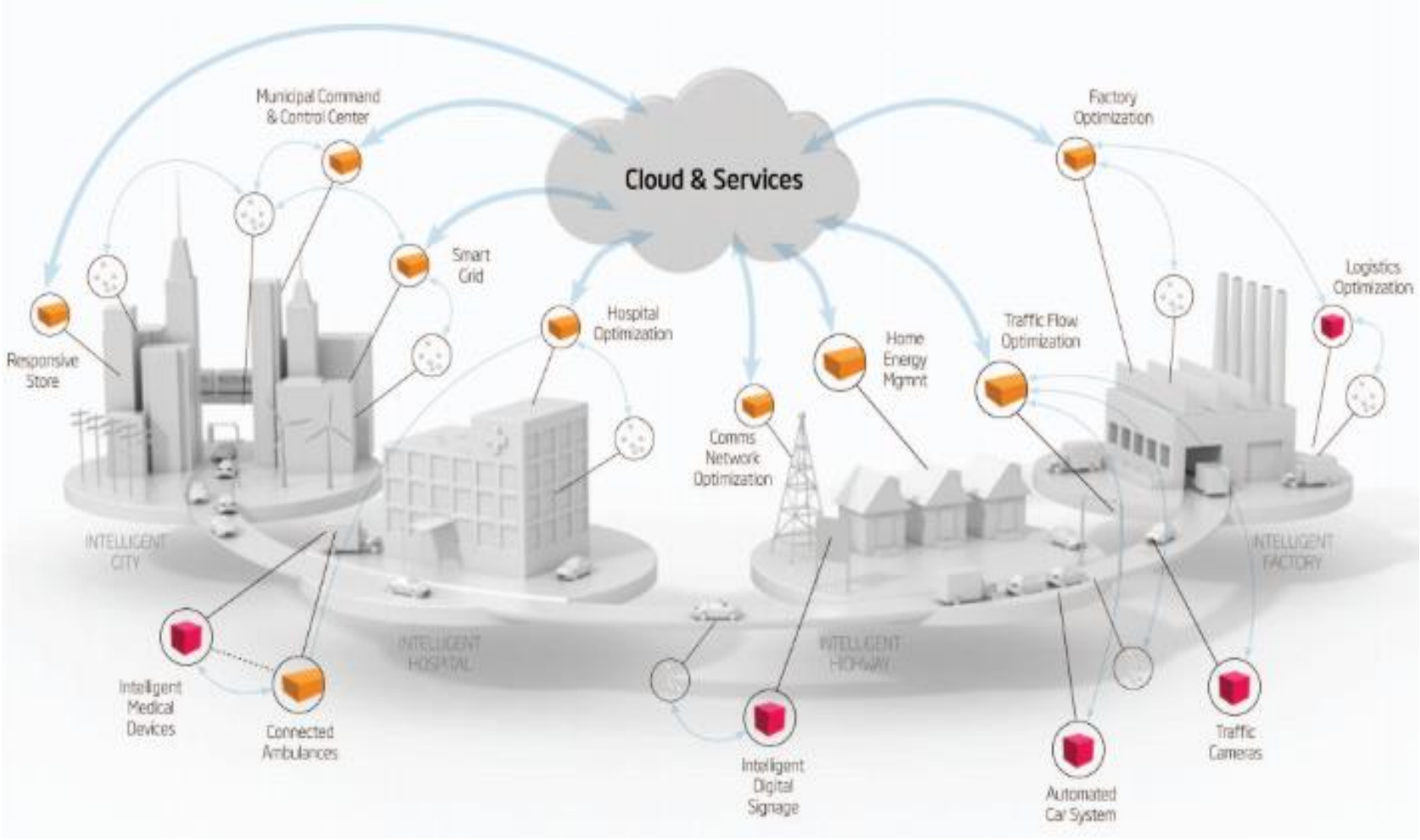
Maxim Integrated 2014



WoT - Systems of systems

- The **Web of Things** (or **WoT**) is a concept and plan to fully incorporate every-day physical objects into the World Wide Web.
- The Web of Things is primarily an evolution of the Internet of Things.
- On the other hand, just like what the Web is to the Internet, allow building an application layer for physical objects, or use 3rd party applications.
- The use of embedded devices.

WoT - Examples



CPS - Globally connected systems of systems

- A **cyber-physical system** (**CPS**) is a globally connected WoT.
- Bring embedded systems to the Web. ie: aerospace, automotive, chemical processes, civil infrastructure, energy, healthcare, manufacturing, transportation, entertainment, and consumer appliances.
- Adaptations: collision avoidance; precision (e.g., robotic surgery and nano-level manufacturing); operation in dangerous or inaccessible environments (e.g., search and rescue, firefighting, and deep-sea exploration); coordination (e.g., air traffic control, war fighting);
- The US National Science Foundation (NSF) has identified cyber-physical systems as a key area of research. Starting in late 2006.

CPS - Examples

Ongoing advances in science and engineering will improve the link between computational and physical elements, dramatically increasing the adaptability, autonomy, efficiency, functionality, reliability, safety, and usability of cyber-physical systems.

Underlying Technologies

– Wireless Communications

- Wireless Sensor Networks (WSN)
- Embedded devices, with tiny computers, sensors, actuators and network interfaces,
- Ability to deploy sensors with flexibility and mobility, on the Web
- Allows to retrieve data about objects and interact with them
- New global networks, enabling new applications and providing new opportunities for humanities and business




Smarter World

– Smart from here

- Today, the world has 340 trillion trillion trillion unique IP addresses [Maxim Integrated 2014]
- Each Person could have zillions of sensors with unique address [Maxim Integrated 2014]
- 60 billions RFID Tags embedded across entire ecosystems
- many manufactured items, goods or assets today utilizing the Internet of Things are already Internet enabled, they have capability to talk to Internet, talk to each other, talk to service providers and talk to infrastructure and environment

Smart Things – are here to stay

2. IoT and CPS Adoption

- Top 5 Issues

IoT and CPS Adoption

Top 5 Issues

1. **Security** (Data, Asset, Resource, Humanity, Safety, Privacy)
2. **QoS and Reliability** (Service Guarantee, Trust)
3. **Disaster and Outages** (Risks, Losses, Consequences)
4. **Cost and RoI** (Capital expenses)
5. **Big Data** (Heterogeneous, Multi-sources, Large n Complex)

3. IoT and CPS Solutions

State of Art Progress

Embracing New Technology

Top 5 Issues

1. **Security** (Data, Asset, Resource, Humanity, Safety, Privacy)
2. **QoS and Reliability** (Service Guarantee, SLA, Trust)
3. **Disaster and Outages** (Risks, Losses, Consequences)
4. **Cost and RoI** (Capital expenses)
5. **Big Data** (Heterogeneous, Multi-sources, Large n Complex)

Top 5 R&D

1. **Embedded System**, both software and hardware (ZigBee, Silicon, Blue tooth,..)
2. **Autonomous Computing**, Industrial Agents, AI, ML, Onto-Auto ,…
3. **Self-organization** (frameworks, models, techniques, policies, processes,
4. **Planning, Prediction and Forecast** (Coalitions, Time of Usage Pricing..)
5. **Predictive, Descriptive and Prescriptive Analytics**, Conjoint DM, Data Lake, Dynamic Data Mart.

IoT Deployment – Security

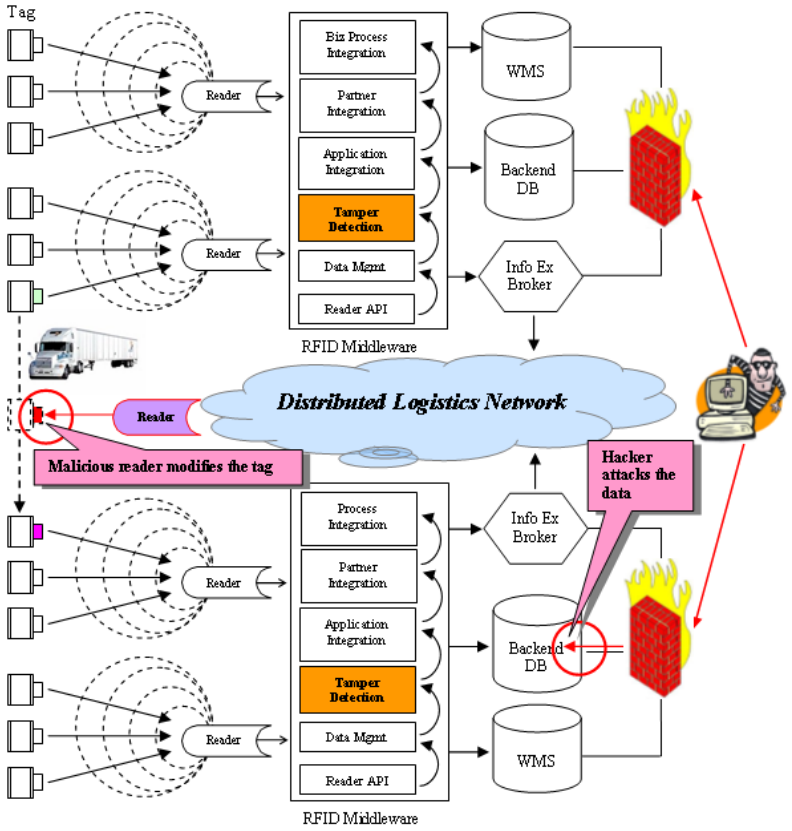
- Demand Build-in security, **software and hardware**
- Silicon, ZigBee, ZigBee Pro, Blue Tooth
- Silicon algorithms: AFS and elliptic curve cryptography, MAXQ1050, MAX32590 secure micro-controllers, bootloaders, life cycle protection of devices.
- Security cameras, like ATM,
- Supervised multitude of remote distributed sensors and control devices and health sensors
- Detection on falsifying sensors data, underreporting consumption, resulting power shut down.
- Algorithms: AES-128, secret keys, alarm standard, cryptography, stenography,
- Risks, Trust, Cyber and ambient Security, Intrusion detection, Machine to Machine communication

Our Work- Tamper Security

Security help identify and measure the network vulnerability, monitoring and control of malicious activities. It also detects the attacks, fraud, and intrusion etc. [Potdar, Chang etal 2005-2013]

Technology underpinning the above are:

- Cyber Security
- Network Security
- Data and Database Security
- RFID tamper detection
- Barcode Watermarking
- Information Security
- Finger Print



Our Work ZigBee Attack Experiment

Simulate operations to disrupt, deny, degrade or destroy communication data within nodes, hub and networks. [*PhD theses and Publication available*]

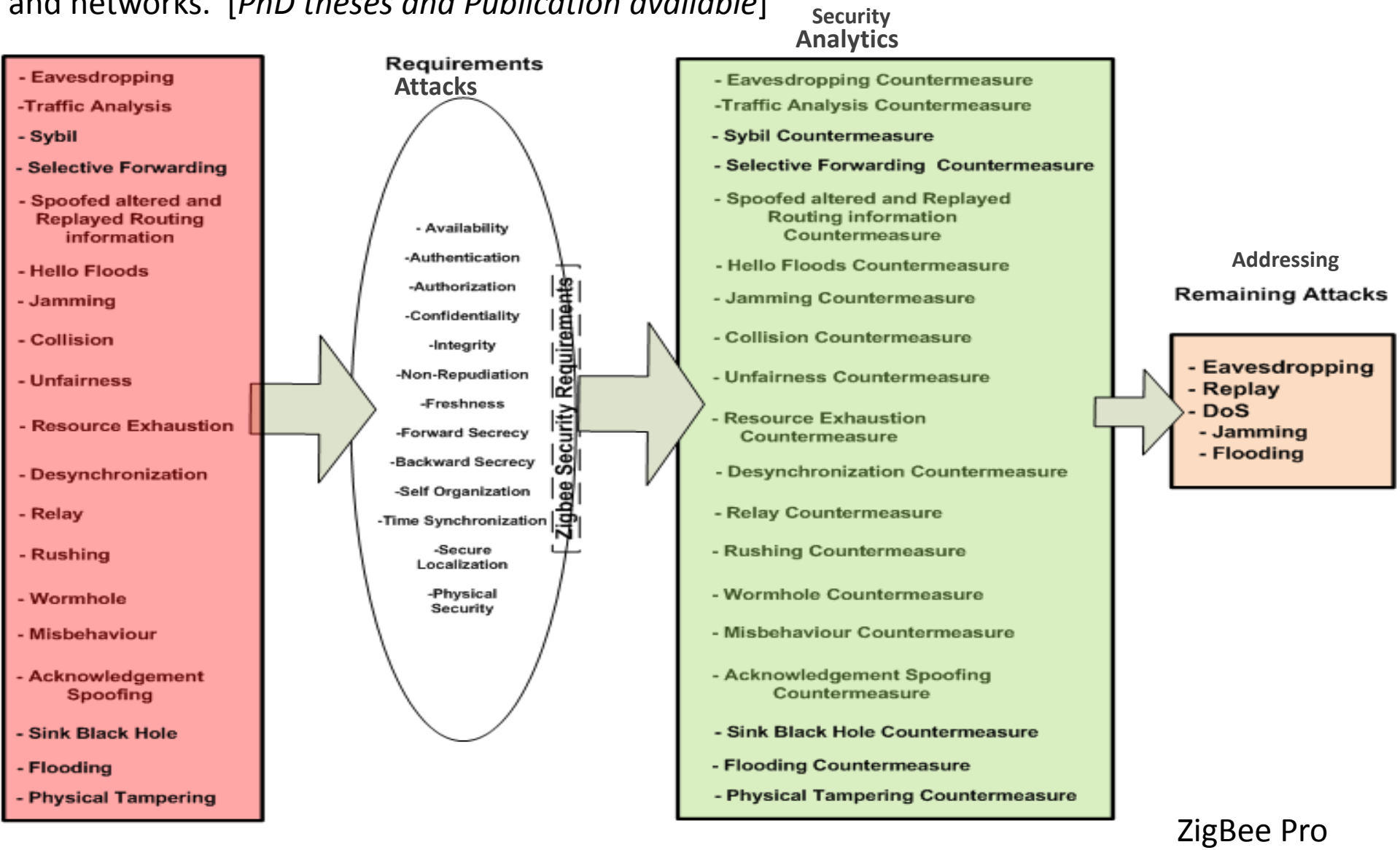
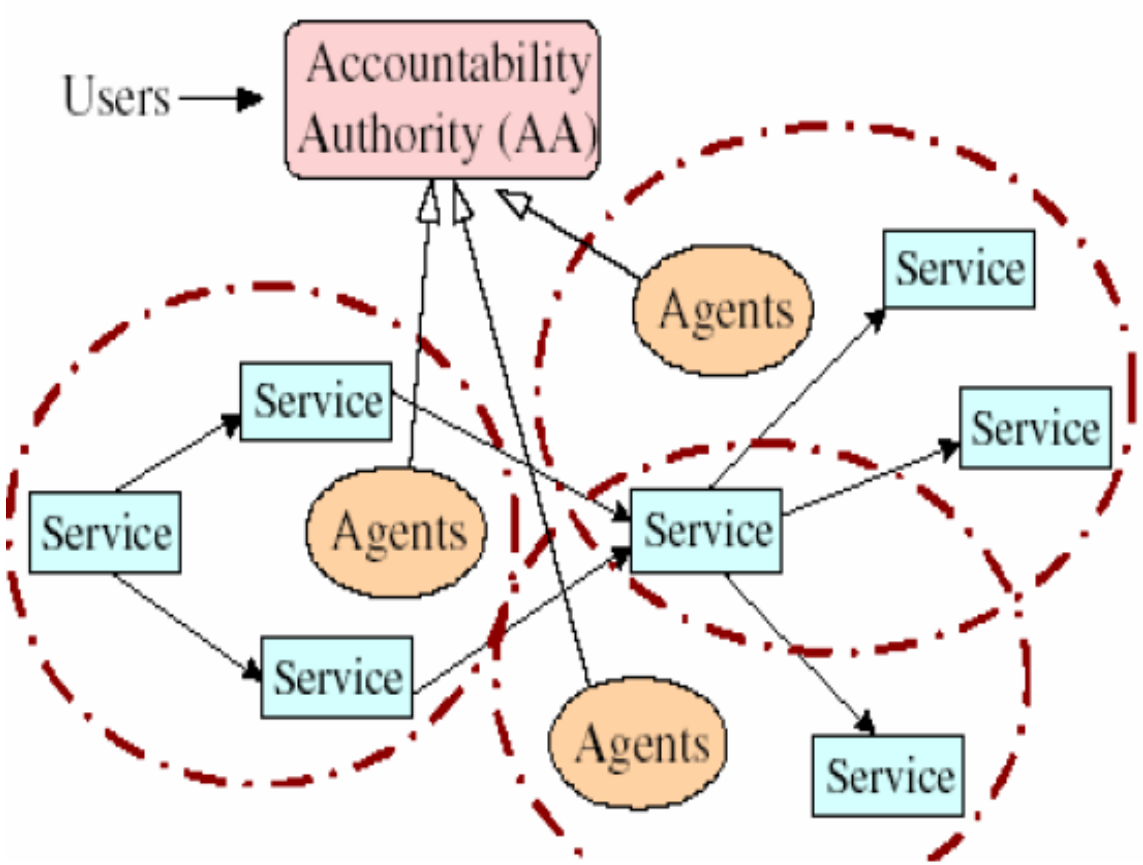


Figure 4-1: The process of Attacks Filtering

Research – Autonomy

- Dynamic management Schemes
- Situation awareness
- Global self-organized network
- Evolution theories
- Regulation Mechanism
- Random service detection
- Service discovery and configuration



Research – Self-organization

Our work:

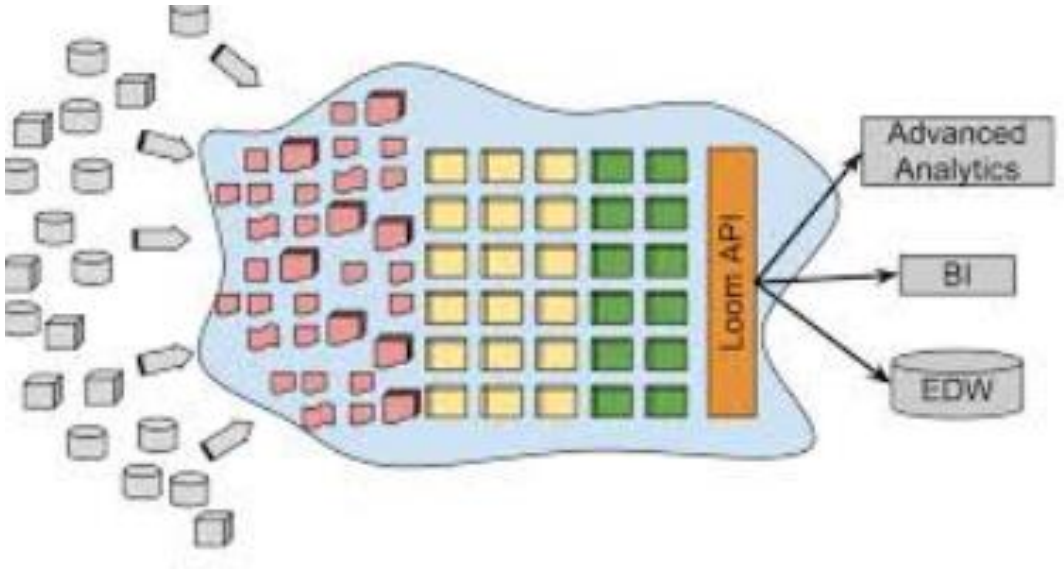
Architectures, Models,
Temporary coalition
Multipath algorithms
NS2 simulations
Fault tolerance
Geo graphic protocols

Research – Big Data, DataMart, Data Lakes

Our Recent work:

Dynamic DataMart scheme.

Data Lake: Data dump, heterogeneous data repository, data integration from multiple sources, dump raw *data* in its native format until it is needed



Loom API | www.revelytix.com

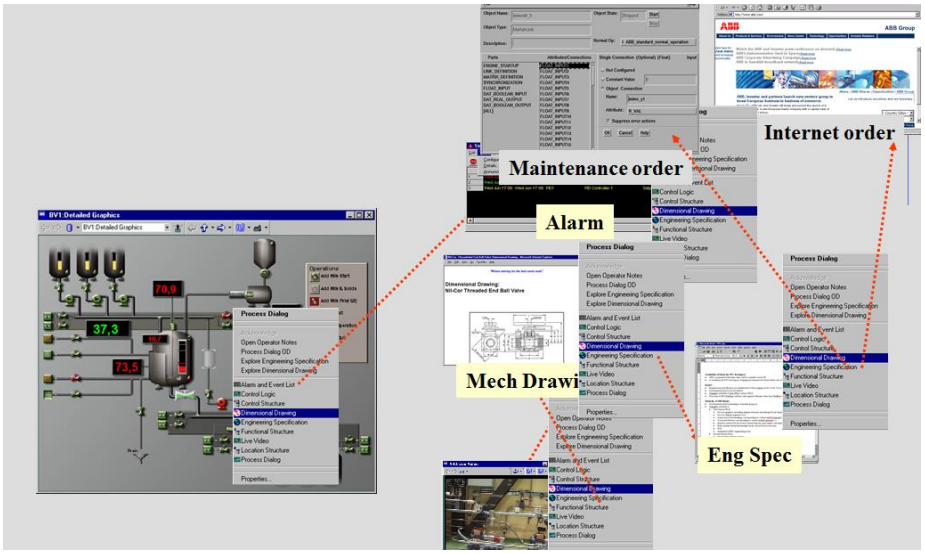
4. Smart Adoption

Face the issues

Make our World Smarter

Manufacturing Adoption of IoT and CPS

The world effort since 1980s



ABB

Power and productivity
for a better world™

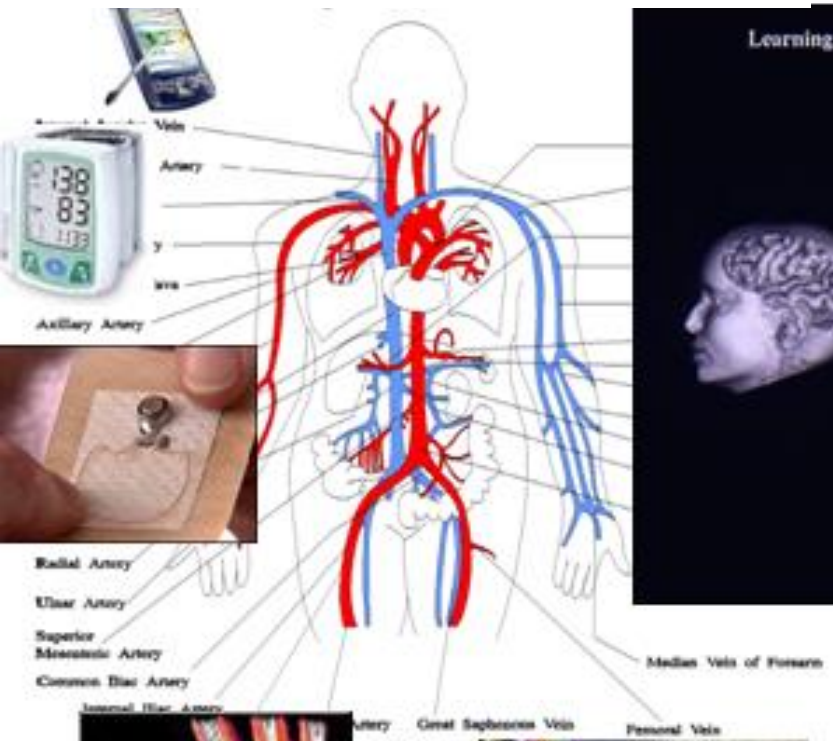
Defence Adoption of IoT and CPS

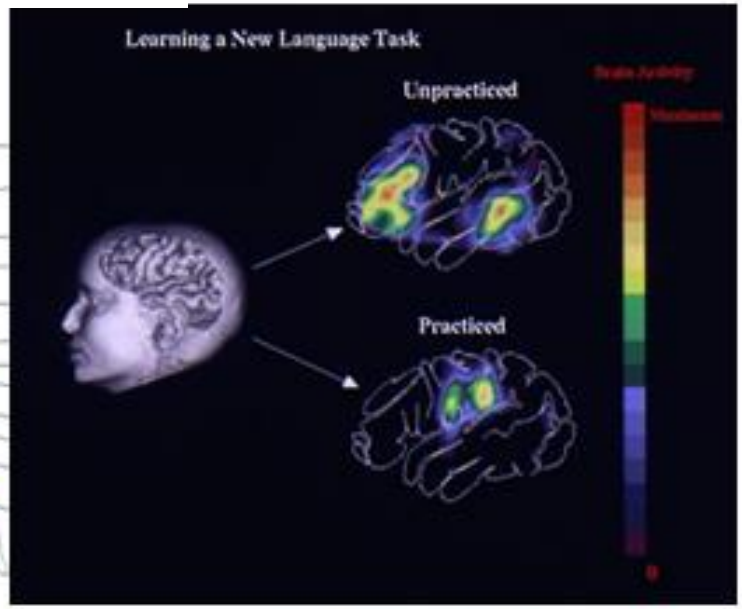
since 1990s

Medicare Adoption of IoT and CPS

The world effort Since 2000s

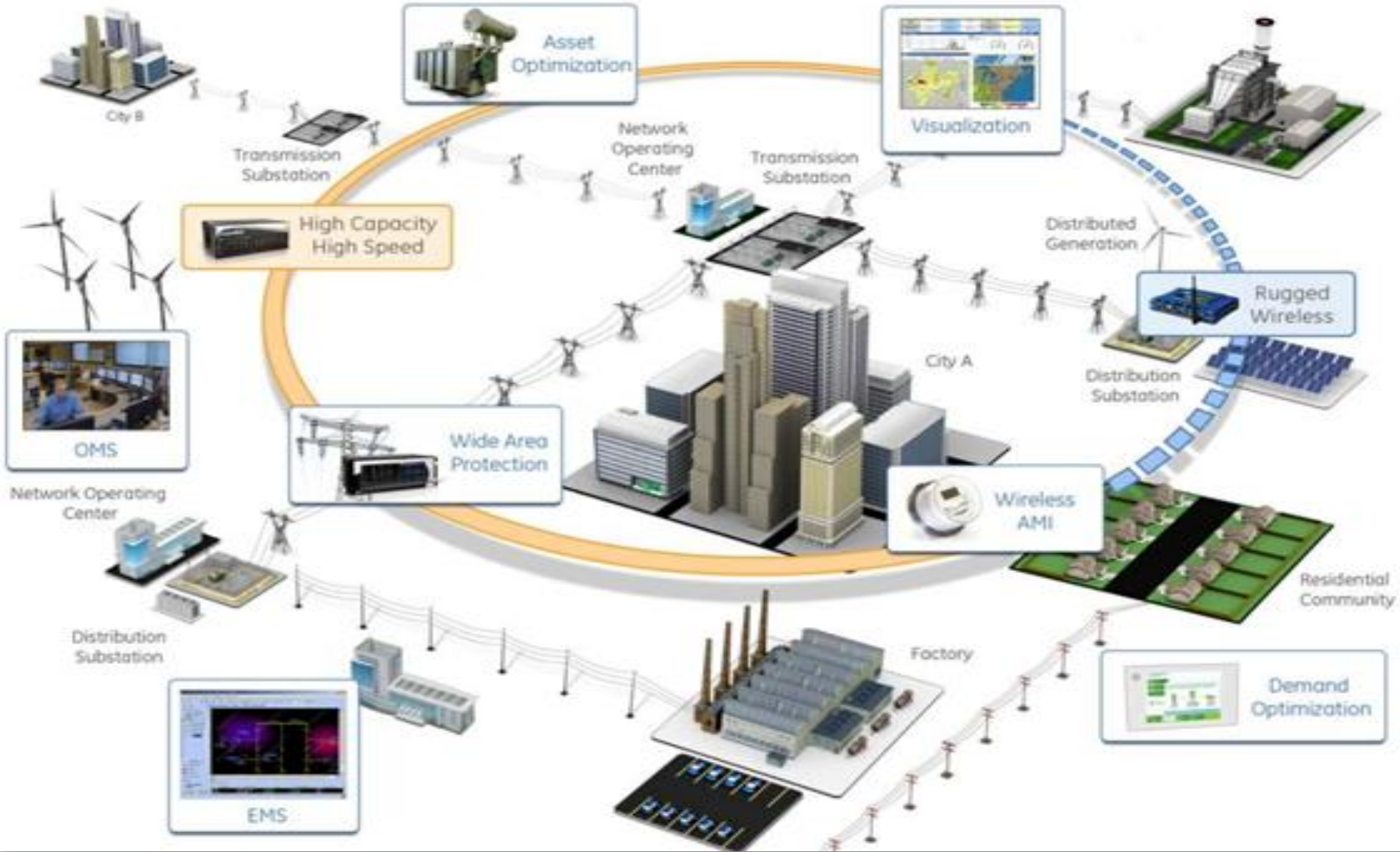
Robotic surgery and remote operation





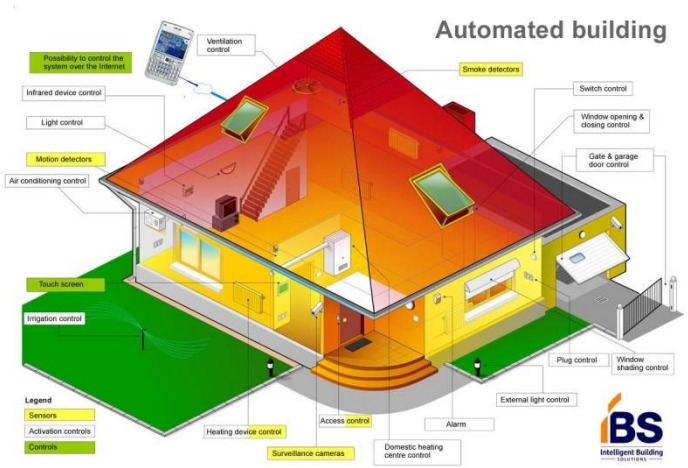
Smart City Adoption of IoT and CPS

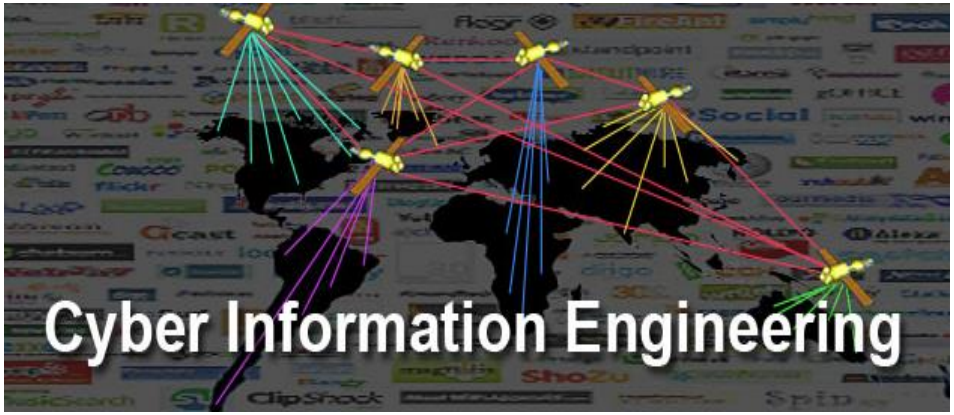
The world since mid 2000s



Smart Home Adoption of IoT and CPS

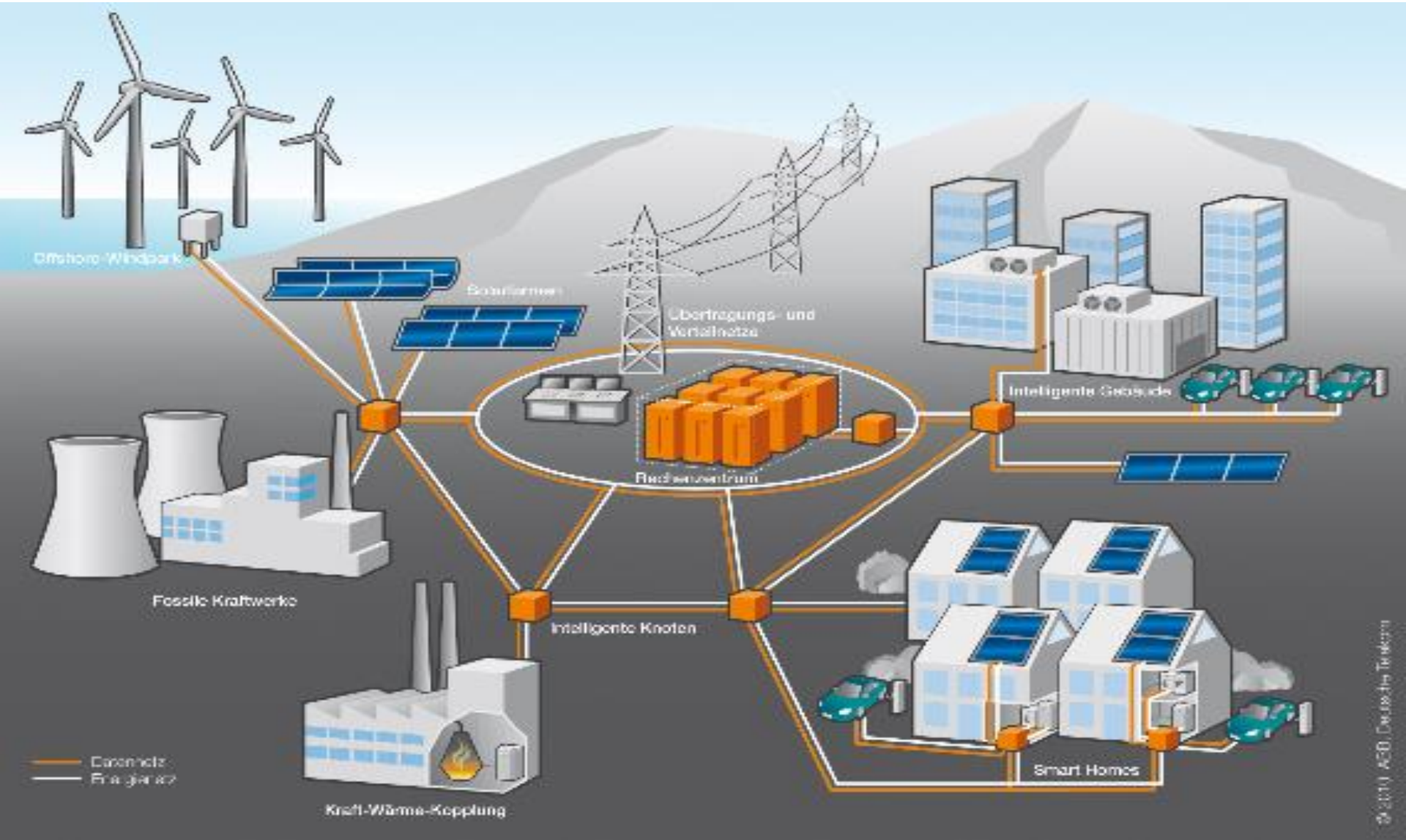
The world effort since early 2010s





Smart Grid - Successful Adoption of IoT and CPS

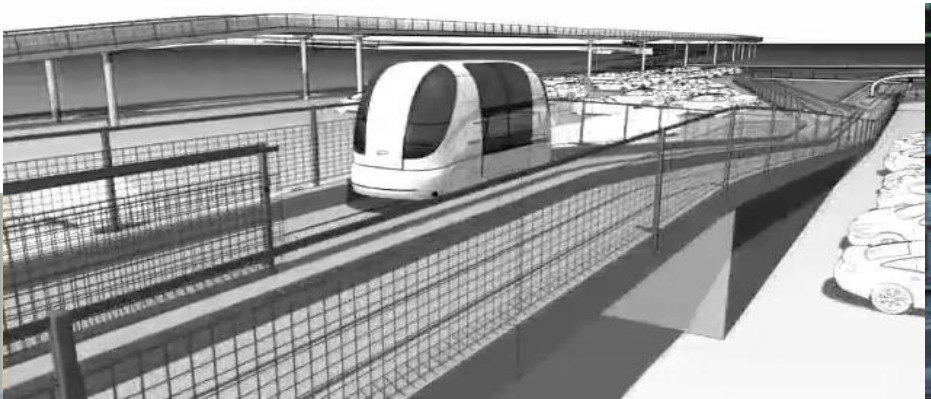
The No.1 successful evidence and RoI



Smart Transportation

The No.2 successful evidence and RoI

http://connectedcarexpo.com/smart-transportation-innovation-coalition-stic/



Our work 2008-2010 funded by StatoilHydro

Mining Industry Project with IoT and CPS

Wireless Sensor Network for Oil Company

ABB SKF StatoilHydro IBM AKER KVÆRNER

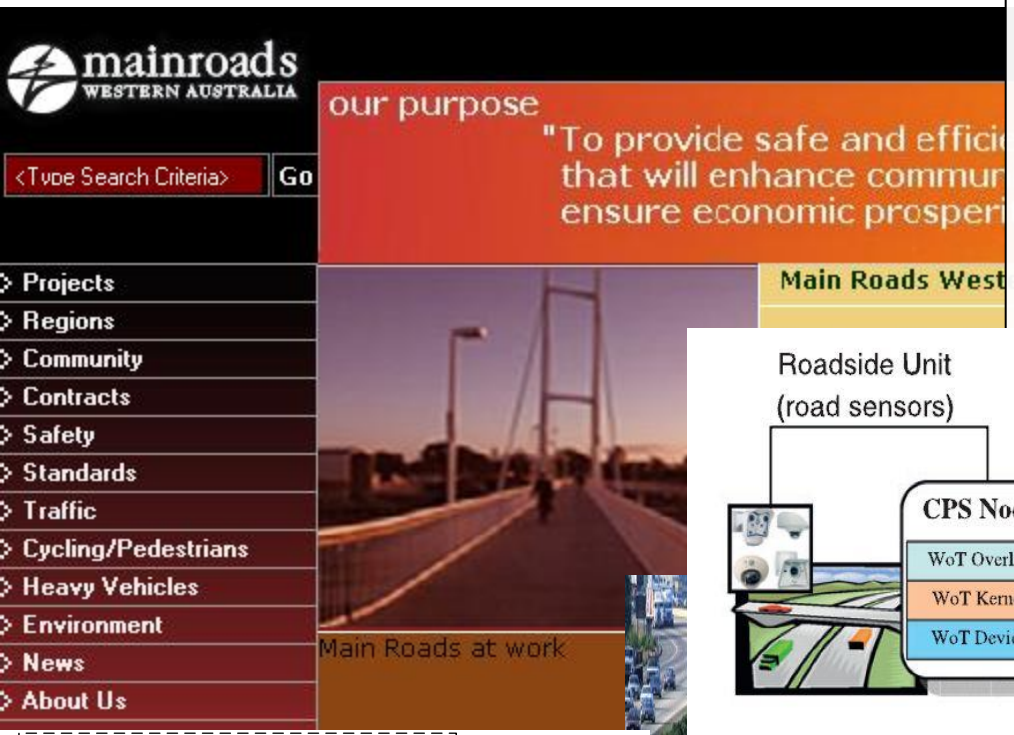
- **StatoilHydro** is involved in large scale exploration of crude oil.
- All their facilities use a **lot of sensors** and wireless devices.
- These devices **provide real time information** on the operations.
- **Failure** of these sensors in **costly** and takes time to get the plant back on track.

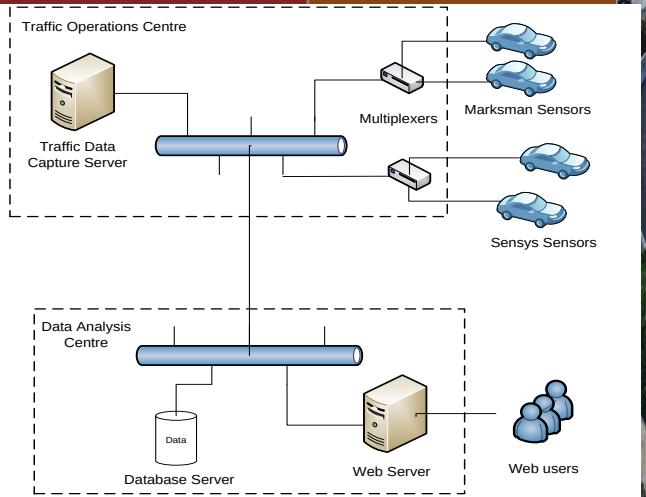
For example

Accumulated sand in the pipes
Limit – up to 200nm acceptable
IF above this limit THEN
Alarm sounds and the Plant Stops
This event is costly and needs to be prevented

Our Work 2009-2012 Funded by ARC and Main Road WA

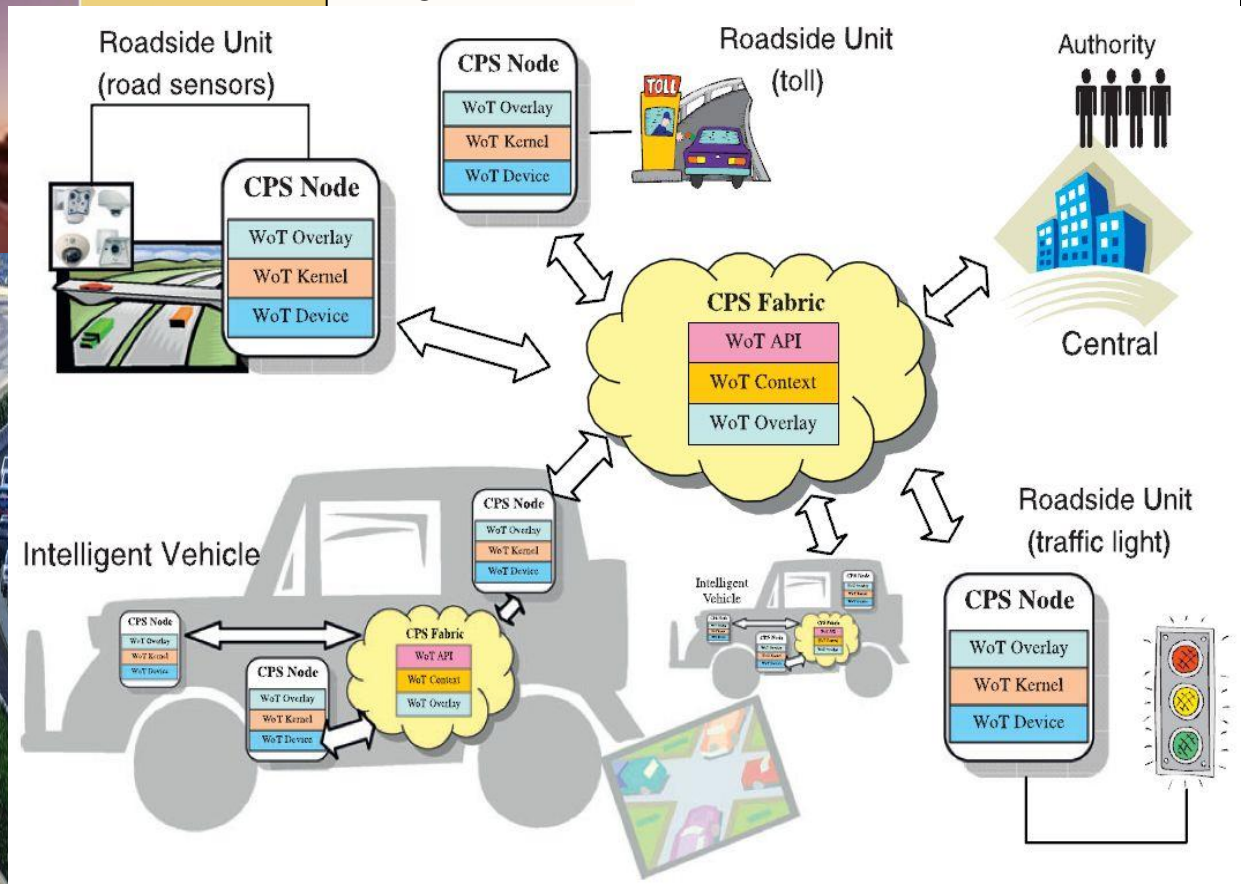
Traffic Control Project with IoT and CPS





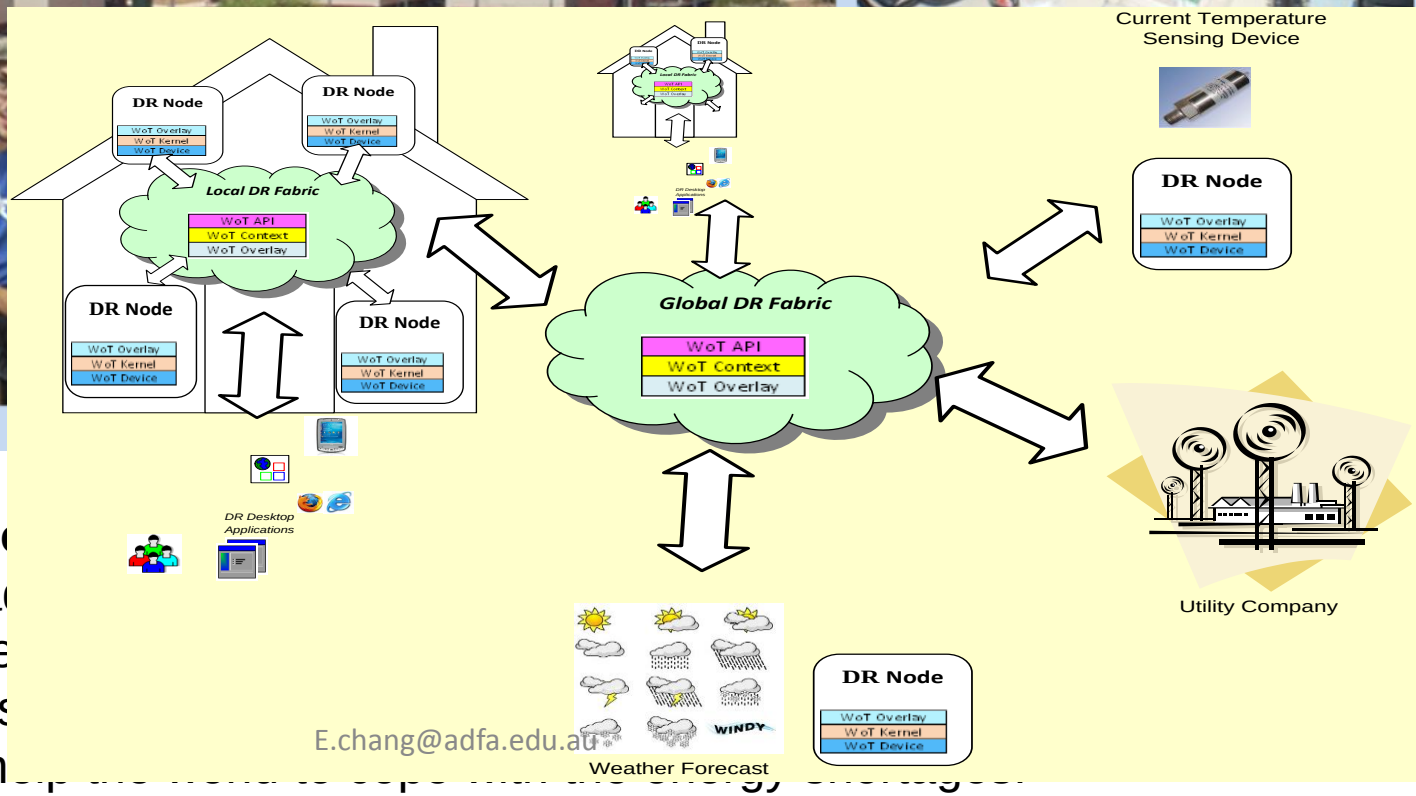
Real Time Traffic Prediction using Wireless Sensor Networks & Real Time Data Mining

Aims:



Our work 2010-2013 funded by ARC and Fleetwood

Smart Energy Usage with IoT and CPS



Smart Fleet Camp Pr

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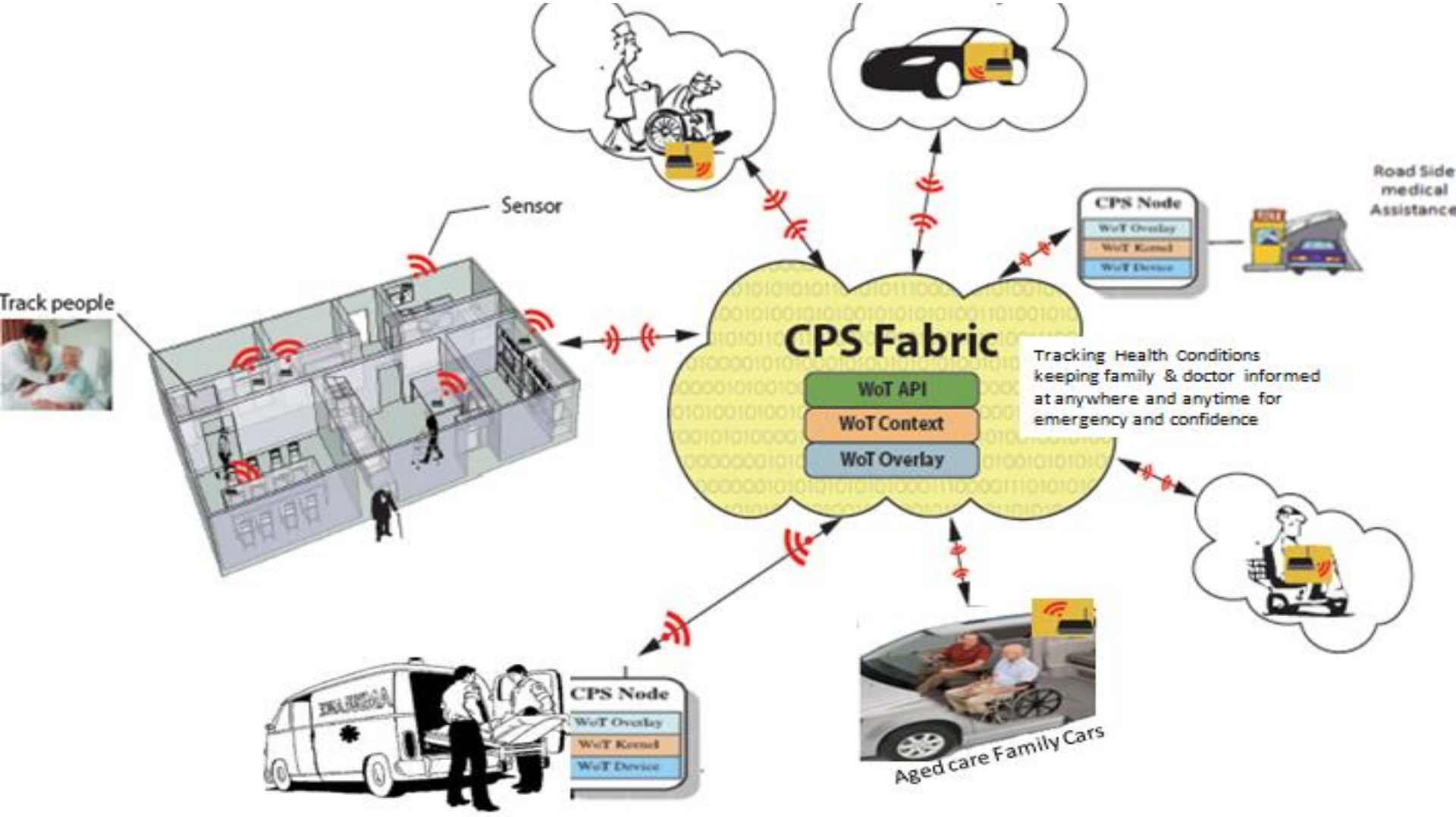
monitoring system. This

from Industry and will h

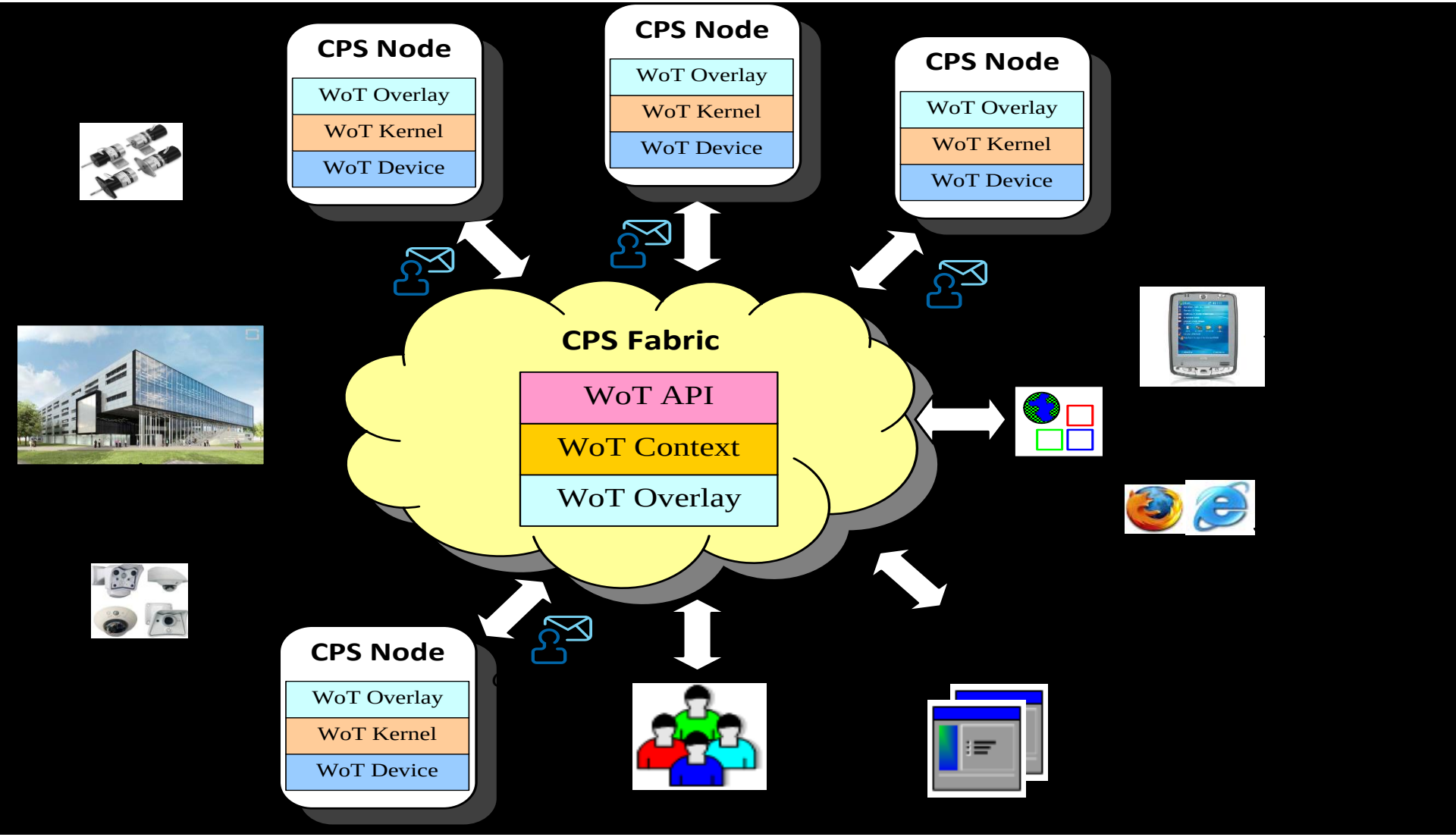
E.chang@adfa.edu.au

Our work 2011-2013
Health/Aged care with IoT and CPS



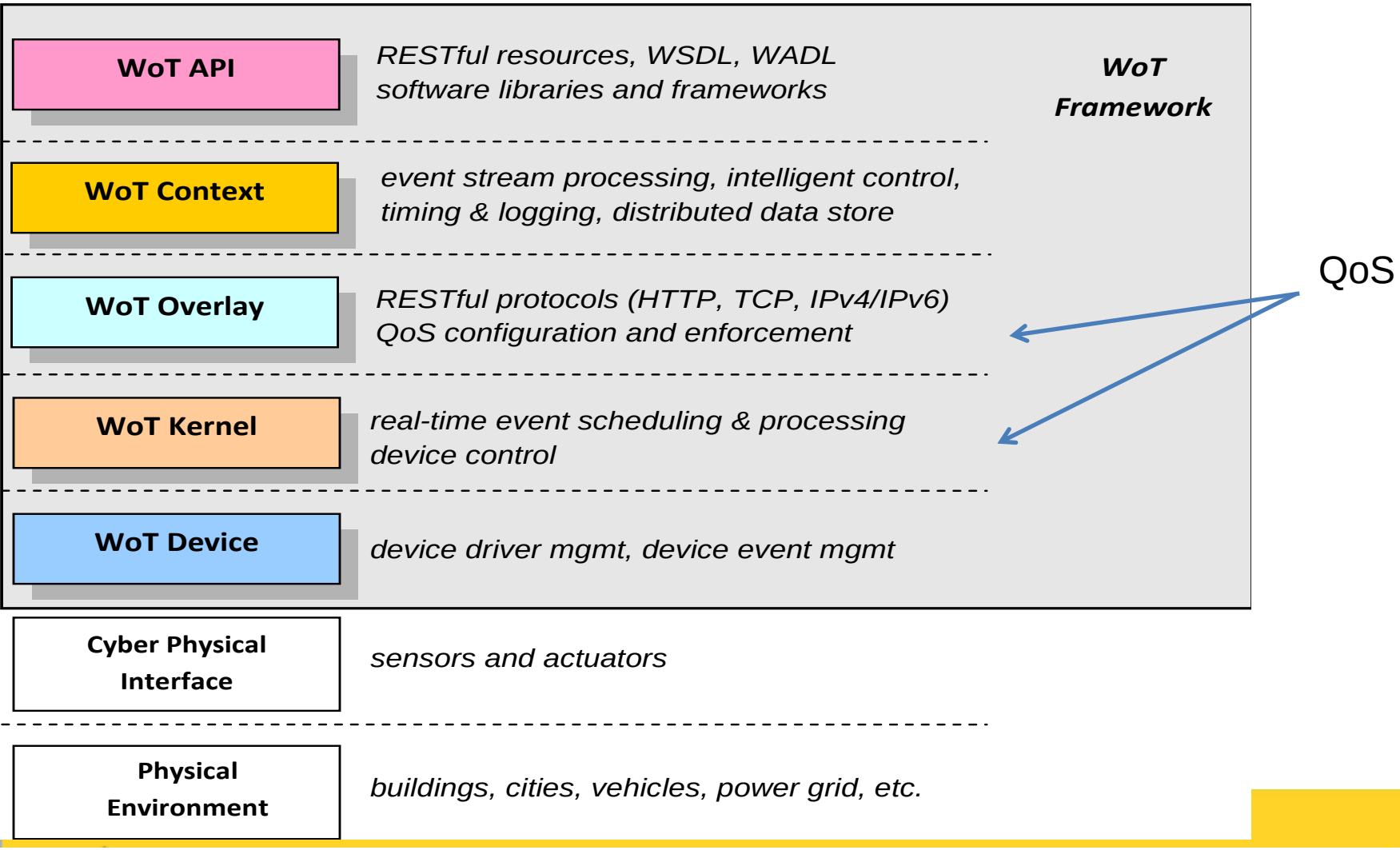
Intelligent Cyber-Physical Systems for Aged Healthcare anywhere anytime

Architecture



"Web of Things Framework for Cyber-Physical Systems," Concurrency and Computation: Practice and Experience, 23(9), 2011, pp. 905–923 ; With T.S. Dillon, H. Zhuge, C. Wu, J. Singh

Our CPS Architecture - based on WoT



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5. Smart Ship

– Top 10 Issues

Our recent work funded by ADF 2014-2018

Ship and Types

Baselines

- Small ship: 13,000 + items, Large Ship 45,000 items
- Small warehouses or Floating warehouses
- 1 – 6 months journey Assets supply
- People, Foods and Medical supply
- Reliability, security and safety

Top 10 Issues for On-Board Ship

1. Security and Safety
2. Communication issues
3. On-Shore and Off-Shore Asset Visibility
4. Manual Data Entry System on-board ship
5. Engineering Reliability and Maintenance
6. Ship Tracking and Sustainment
7. Long Lead Time
8. Repairs n Overhaul
9. Poor Demand Planning
10. Un-balance Ship Inventory and Budget

Top 10 Issues for On-Board Ship

1. Security and Safety

- Human Assets
- Physical goods assets
- Defence services
- Piracy attacks
- Privacy
- Safety
- Financial responsibility

Top 10 Issues for On-Board Ship

2. Communication issues

- On and off communication
- Whether conditions
- Access to satellite
- Data exchange – normally 24 hrs delay (communication load, encryption, extraction, txt packet send/receive)

Top 10 Issues for On-Board Ship

3. On-Shore and Off-Shore Asset Visibility

- End-to-end Data visibility
- Data Misalignment
- Data Entry Error and Data Reject
- Track n Trace Spares,
- Track n Track “usuage” and “returns” (broken ones)
- Financial Accountability

Top 10 Issues for On-Board Ship

4. Manual Data Entry System on-board ship

- Manual based data entry
- No automation support
- Error-prone
- On-shore and off-shore data alignment
- On-shore and off-shore systems' communication

Top 10 Issues for On-Board Ship

5. Engineering Reliability and Maintenance

- Keep pace with scheduled maintenance
- Outside manufacturing warrantee
- Varied engineering depreciation predictions
- Challenges in Engineering reliability modelling
- Approaches to Engineering replacement

Top 10 Issues for On-Board Ship

6. Ship Tracking and Sustainment

- Identify where about in emergency situation
- Submarine rescue
- Natural Disaster relief
- Substantial cost (financial and human resources)
- Substantial damages

Top 10 Issues for On-Board Ship

7. Long Lead Time

- Repair loop between 6 weeks to 6 months
- Lead time to “issue” (delivery the parts)
- Lead time to “Return” (return the broken parts)
- Repair pool estimation
- Balance between Schedule vs un-schedules maintenance

Top 10 Issues for On-Board Ship

8. JIT Repairs and Overhaul

- Engineering diagnostics
- Engineering Expert
- Data Expert
- Budget constraints
- Inventory forecast
- Inventory planning

Top 10 Issues for On-Board Ship

9. Poor Demand Planning

- Older Platforms
- Un-expected breakdown
- Difficult to forecast
- Multi factors and multi variables (Operator behaviours, Usage and usage rate, engineering reliability, maintenance, etc)

Top 10 Issues for On-Board Ship

10. Un-balance Inventory and Budget

- Cost of urgent repair
- Poor “safety Stock”
  (what you need, you do not have, what you don’t need, you have plenty)
- Cost–to-hold
- Optimisation of Inventory
- Optimisation of budget
- Buy vs repair decision
- Value for money

Top 10 Issues for On-Board Ship

1. Security and Safety
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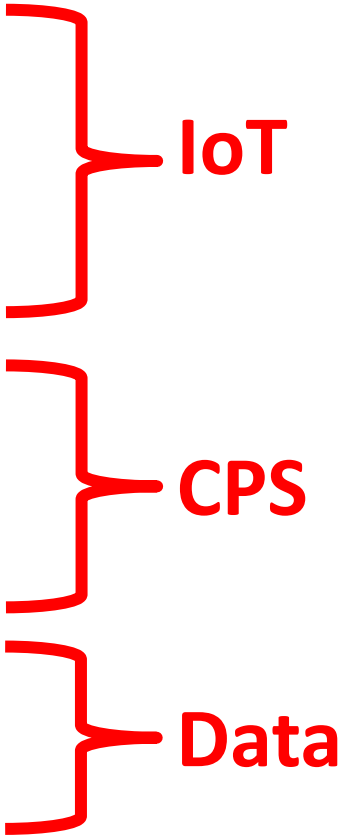


5. Smart Ship Solution

– Embrace new Technology

Existing Work

- Safety and efficiency of inland shipping [2013 http://ascelibrary.org/doi/pdf/10.1061/9780784413036.327]
- Ericsson's Maritime ICT Cloud, connect vessels at sea with shore-based operations, [2015 http://www.landmobile.co.uk/news/ericssons-maritime-ict-cloud-enables-connected-ships
- Route Exchange, connect Maritime cloud, services, stakeholders and geolocation of ships [2015 Application REX http://osdelivers.blackducksoftware.com/2015/02/11/industrial-internet-of-things-in-the-maritime-industry/
- Signal K: connect all the previously disconnected Things on the boat into a Network of Things http://themarineinstallersrant.blogspot.com.au/2015/02/iot-and-your-boat.html

IoT for Smart Ship

Our solution (IoT, Voice, RFID, MobApp)

Tightly coupled and controlled system

Ship Top Issues

Security and Safety

Communication issues

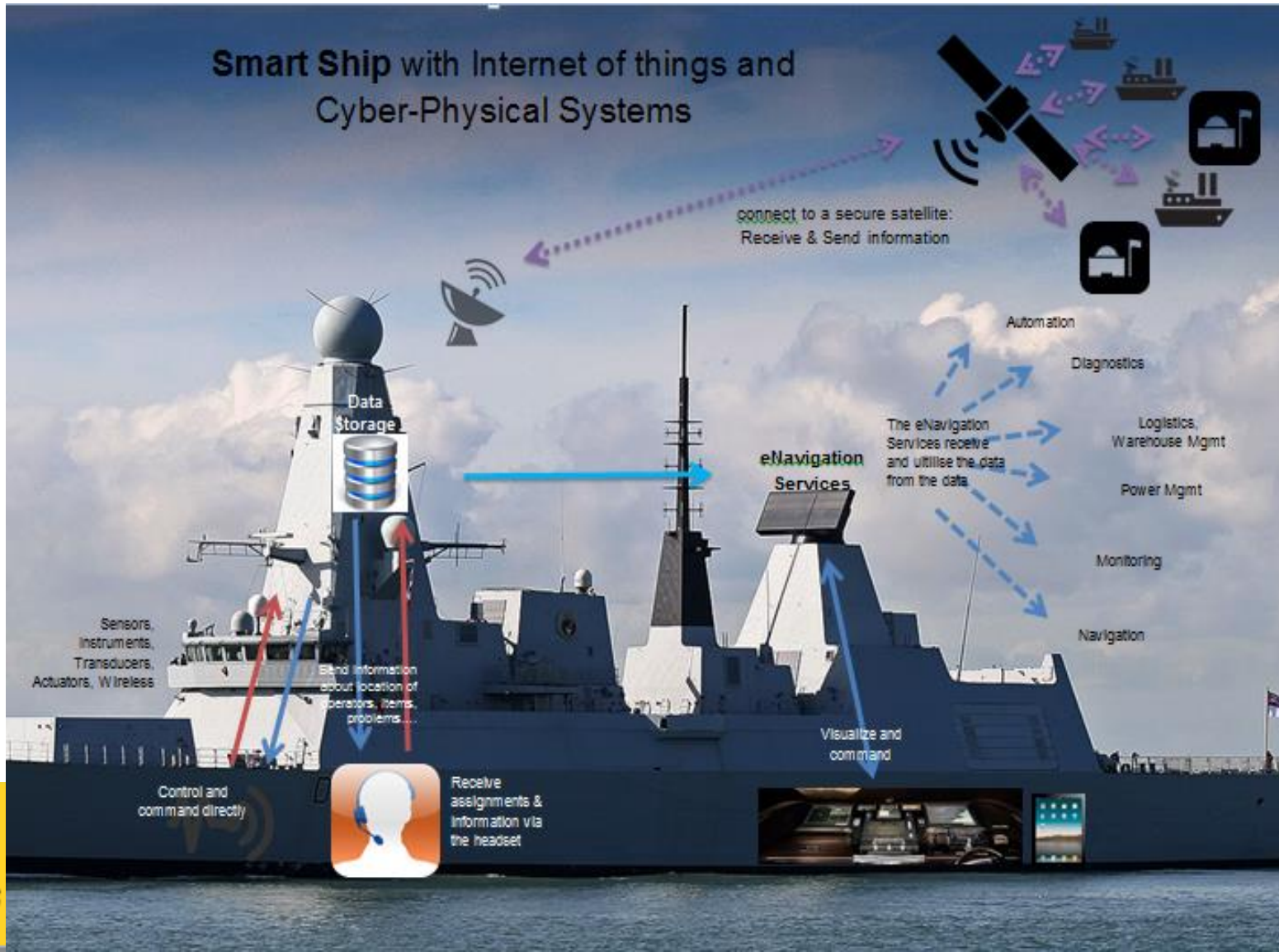
On-Shore and Off-Shore Asset Visibility

Manual Data Entry System on-board ship

Engineering Reliability and Maintenance

Our proposed work

- Voice headset, locations of each item…
- share this information inside a single ship
- use voice for managing the ship and sending information.
- monitoring, navigation, asset movement
- Location of operators , assets and via a sensor or the headset
- Managers to assign orders



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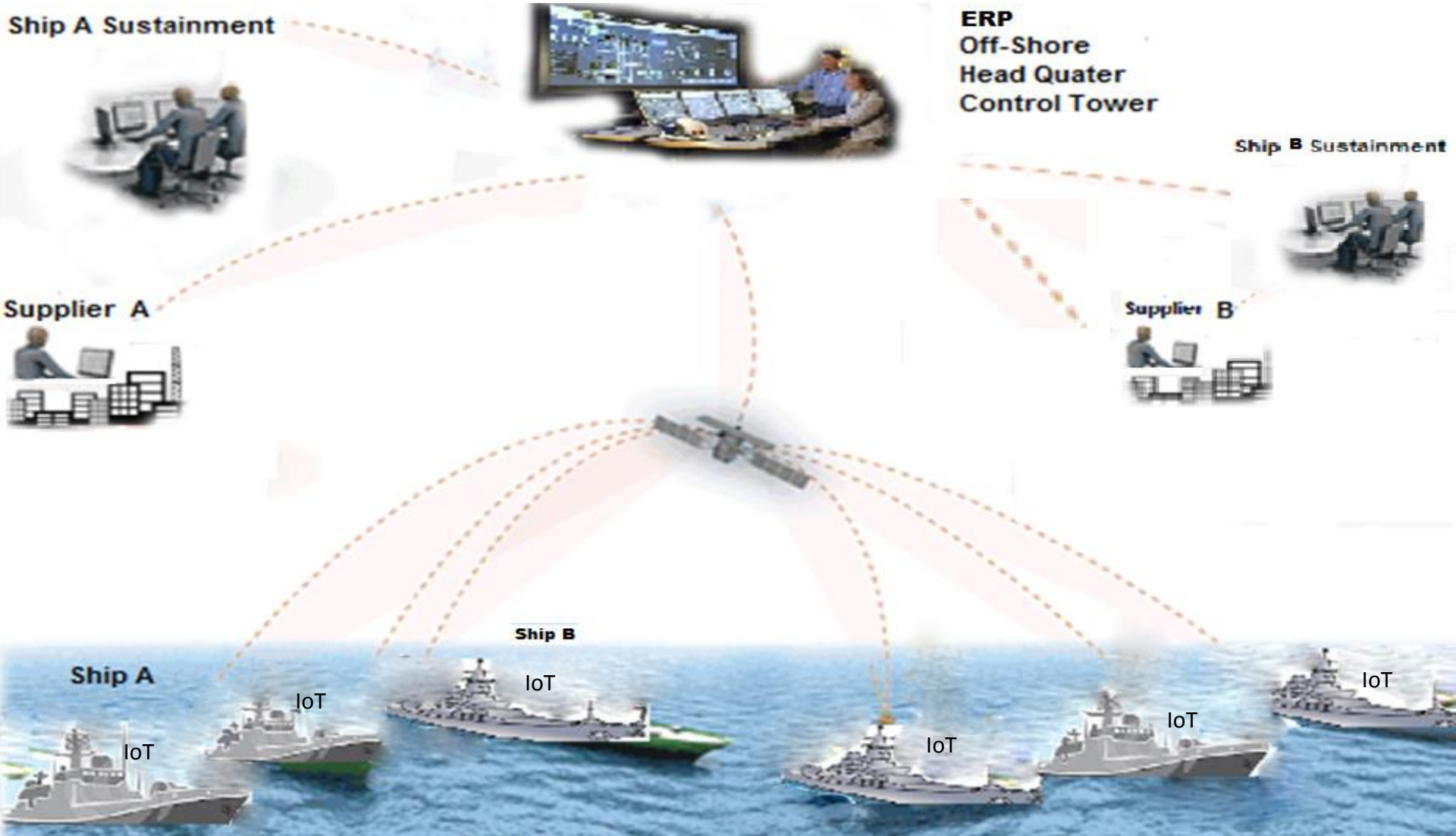
Smart Ship with CPS

Our solution (on-shore+ Off-shore, Sys Integration, E-to-E Visibility)

Globally connected Systems of Systems

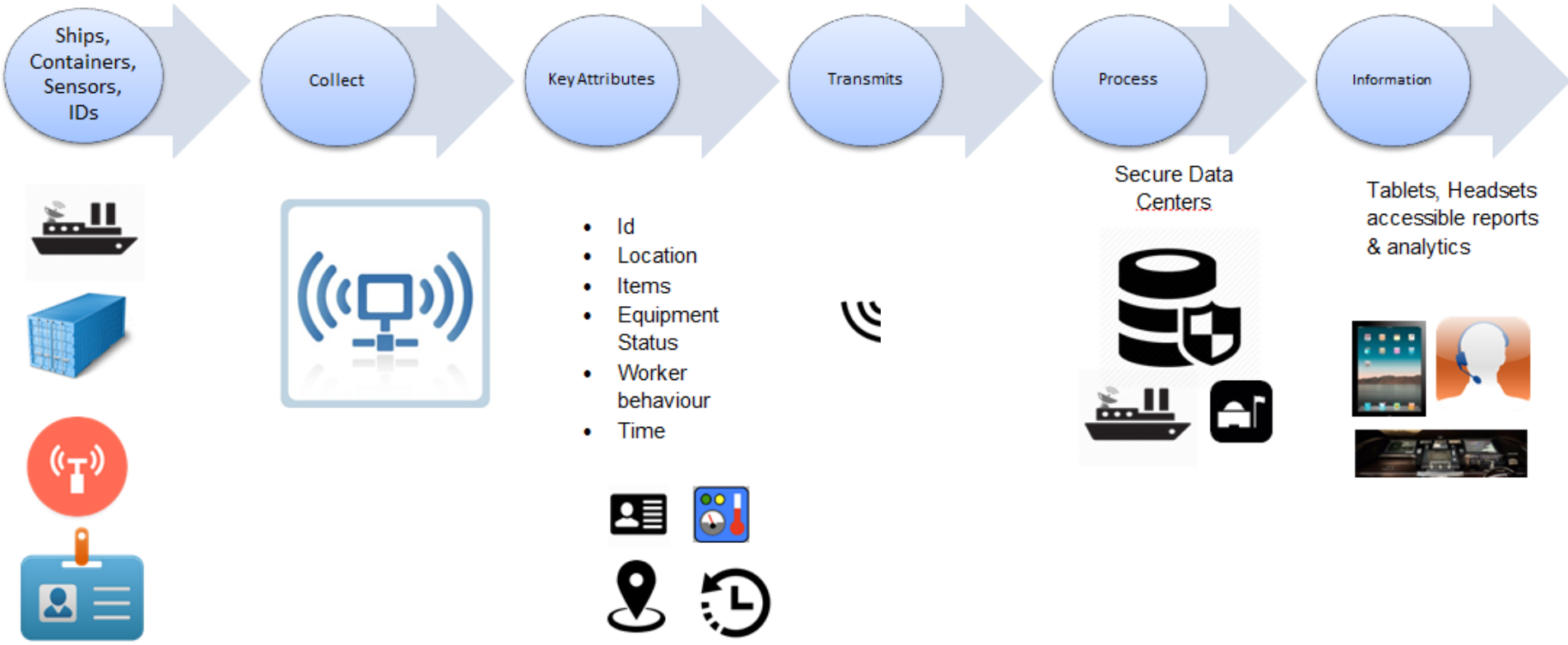
Ship Top Issues

- On-Shore and Off-Shore Asset Visibility
- Engineering Reliability and Maintenance
- Ship Tracking and Sustainment
- Long Lead Time
- Repairs n Overhaul



IoT for Smart Ship

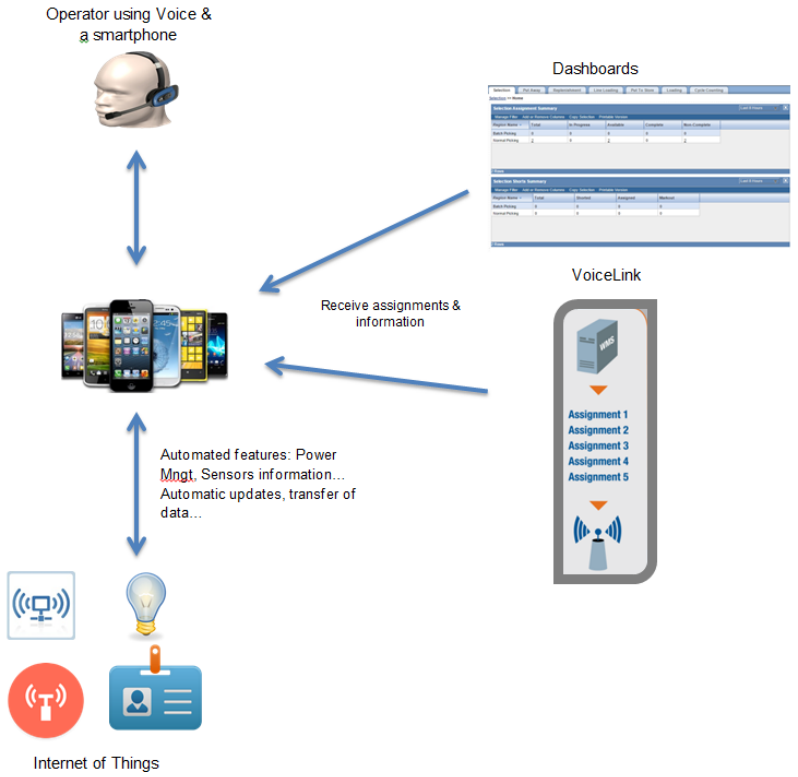
Our Smart Ship Solution Process



Software Integration for Smart Ship

Our Smart Ship Solution integration of RFID, Voice, Data, MobApp,+

Automation	•Controlling equipments by automatic means (gas pump, tank..) •Reduce human intervention&error
Diagnostics	•Receive clear information on dashboards •Reports, analytics…
Logistics	•Improve logistics with tracking devices, and route info of items & ships
Power Mgmt	•Control the power distribution inside the ship
Monitoring	•Vessel positions •Id tracker…
Navigation	•Map updates •Facilitate navigations: recommandations, wheather forecast…

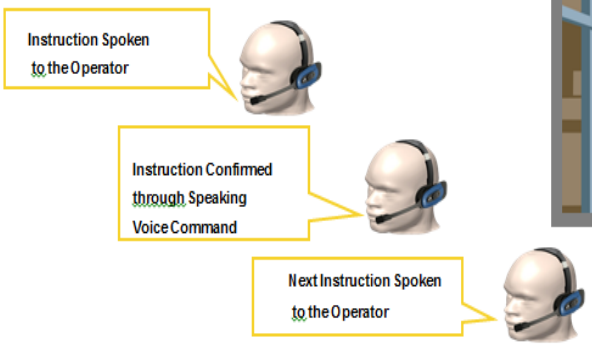


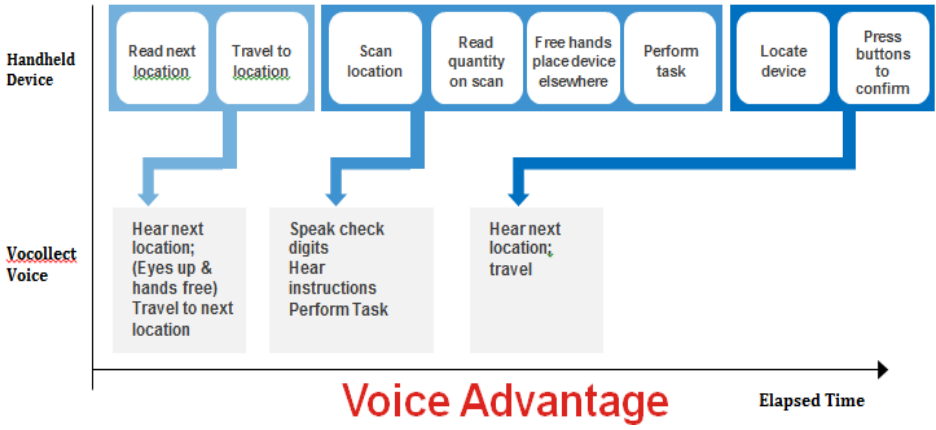
Voice + IoT, Enable Automation

Powered by Honeywell Voice link Technology

a. How does it work

- Assignment from WMS/ERP transmitted to voice-enabled platform via 802.11a/b/g WLAN
- Voice-enabled platform translates assignment data into audible commands
- User provides spoken responses to confirm actions
- Check-digit ensures accuracy
- Translated back to data
- Transmitted from voice-enabled platform via 802.11a/b/g WLAN
- Host data sources updated using enterprise connector





1. Engineering Diagnostics (repair or overhaul)
2. Breakdown scenario outline
3. FastTrack of asset on the on-board ship
4. Urgent demand description
5. Accurate recording of asset usage rate
6. Tracking "Return" of the assets

Smart Ship with IoT n CPS

Conjoint DM and In real time

- The co-joint data and content mining on Big Data including the combined RFID and wireless sensors data on the goods and assets handling, warehousing and transportation, GPS, GPRS and position location system for transport vehicle and shipment tracking, Surveillance Systems for Operator Performance and situation awareness, provenance of Goods and Asset tracking.
- The conjoint data and content mining are also needed for Inter- and intra-ship, on-shore and off-shore transactions; data monitoring,
- Black-box (on ships vessels) communication and auto and semi-automated physical flow and information flow

Challenges on Conjoint DM

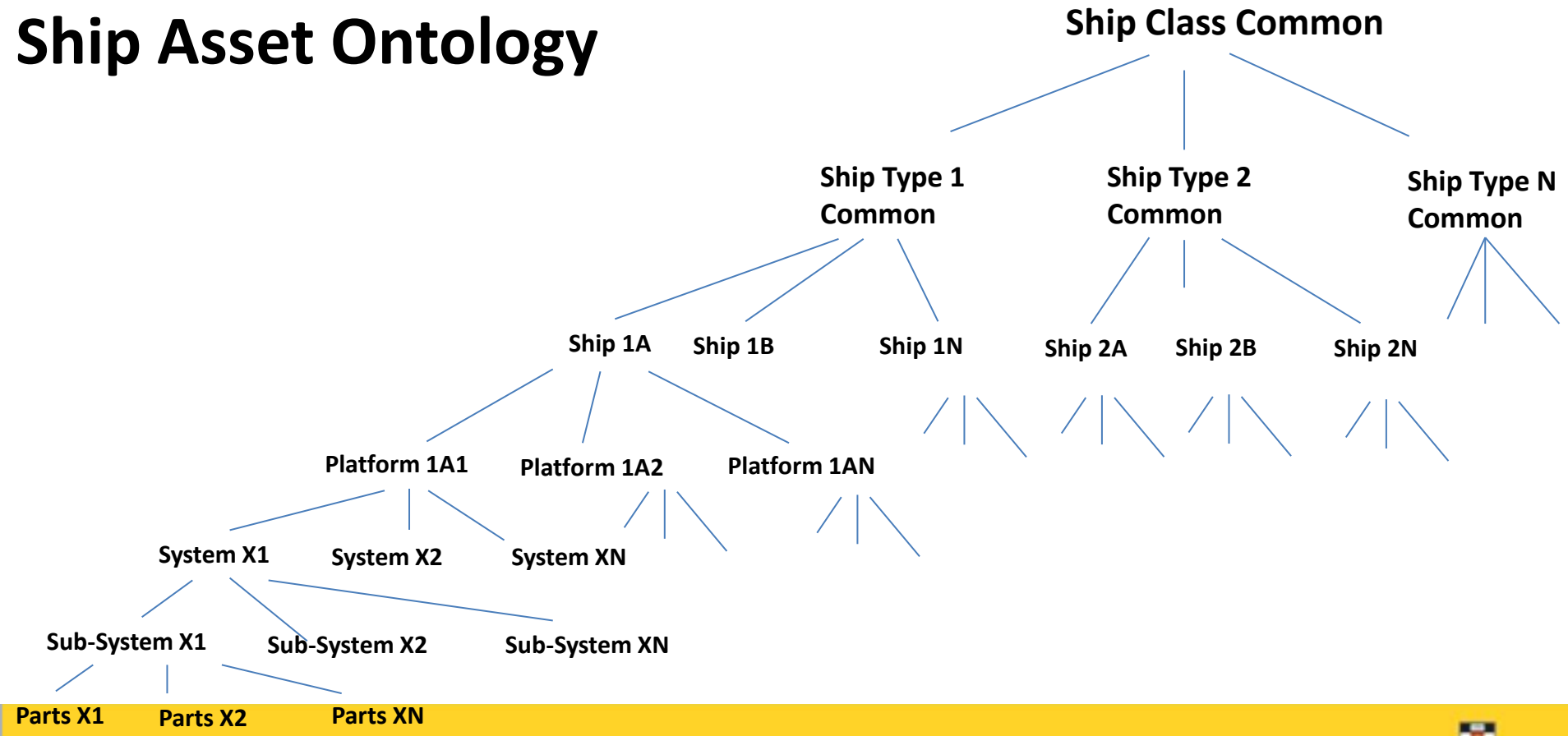
- One of our biggest challenges in the conjoint data mining has been the assurance that the data quality, data are trusted and transmitted securely.
- If the wrong decision is made based on the poor data set, it could result in major financial losses, high casualties and possible terrorist attack through the use of transport.

Conjoint DM + Ship Ontology

- We have developed ship ontology aimed at managing the Big data by defining the meaning of data through adding context that gives information on the data.
- Our works include Ontologies, RDF annotations and contexts. We carry out mining and visualization of big data both relational data (ship warehouse data) and complex data includes tree structured data (Geo-data),
- We work on XML based asset management (procedures and workflows), semi-unstructured textual data, voice data, image data (positions and locations), multimedia data (surveillance data), graphical data (Asset tracking data).

Real time Data Intelligence for Smart Ship

Ship Asset Ontology



Front-end Mobile App

powered by Dynamic DataMart from Data Lake

The Dynamic Data Mart Engine [39, 40] is a forward and backward loop that carries out 3M and 3R functions,.

3M, namely:

- Data Mining: mining the application log, that mines the user's behaviours/user's decision makings and usage rates of each view and window widgets clicks, providing usage rates.
- Data Marshalling: for low usage rate views, we collect the data set, put them on probation period, to see whether we can reuse.
- Data Meshing: based on the data mining and data marshalling report, we create new views that potential will attract the usage.

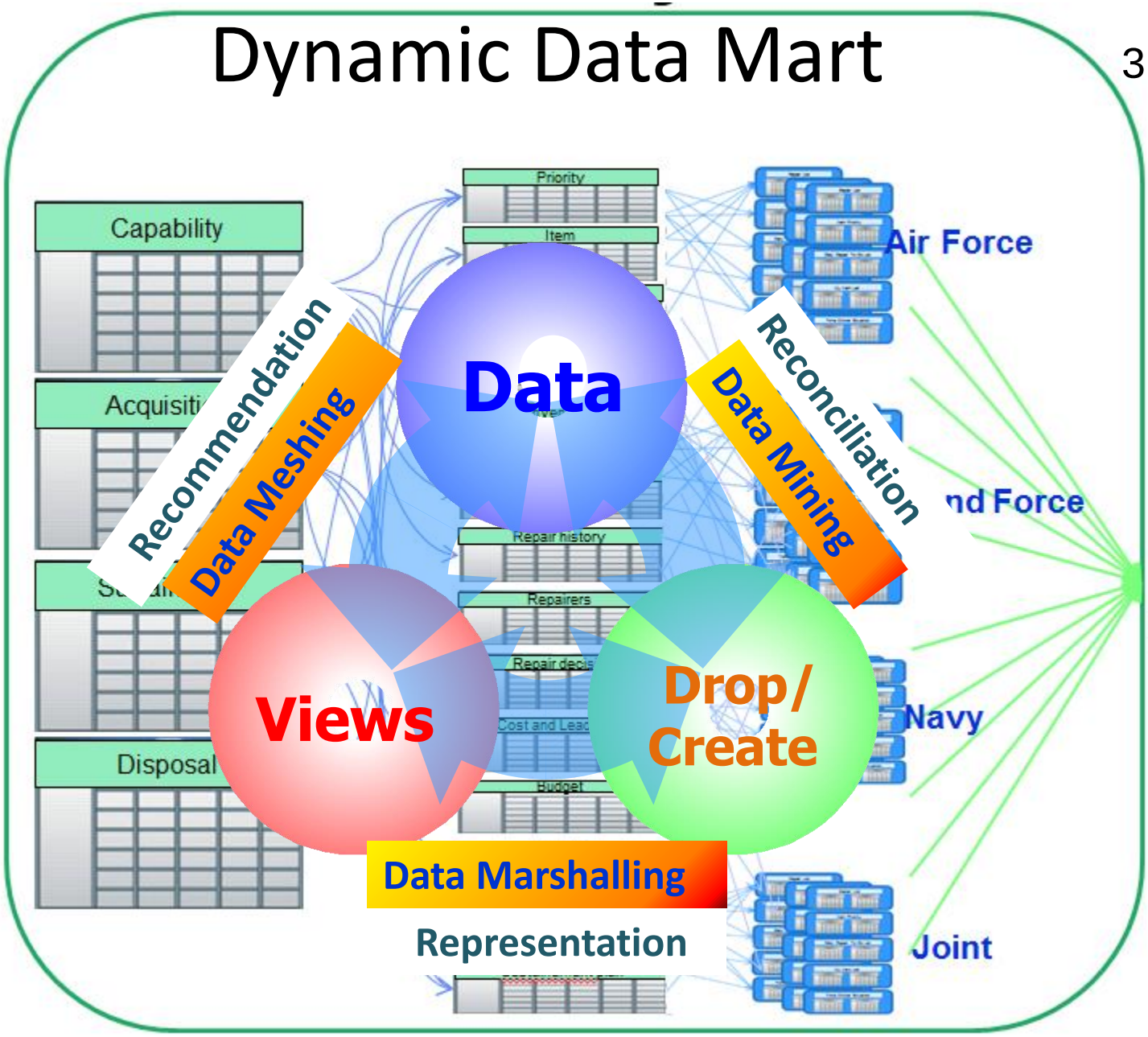
3R, namely:

- Recommendation: Following up 3M, we provide recommendation to the user, just like how Amazon.com gives it to people who have purchased a book by recommending them other similar books that other people have bought to the RI managers, that are likely to use the similar data set and making similar decision, but this decision making is now recorded and reused.
- Reconciliation: If the data is likely useful with high hit rate, but the view is not useful to finish a task, we reconcile all the window widgets and data set, provide new window workflows or widgets workflows.
- Representation: We then represent a new view to replace the old view to the user.

Citation: Chang etal "Dynamic Data Mart", Keynote, IFIP World Computer Congress WCC 2015

Dynamic Data Mart

3M + 3R



Conclusion

Summary

1. **IoT and CPS – New Industrial Frontier**
2. **Top 5 Issues – IoT and CPS Adoption**
3. **IoT and CPS Solutions – Ours and World Effort**
4. **Smart Adoption – The Success Evidence**
5. **Smart Ship – Top 10 Challenges**
6. **Smart Ship Solution – Embrace new Technology**

Conclusion

Unleashing the Potential

Despite mounting political pressures and regulations, about security issues with IoT and CPS

- **IoT and CPS adoption, will be rolled out one by one,**
- **Providing smarter world with great RoI**
- **Preserve precious resources, human lives, fuel, human endeavour, and time**
- **Demonstrate value for money**

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Questions?

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Work experience and PhD programs welcome at UNSW@ADFA