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System of systems
new opportunities and their challenges

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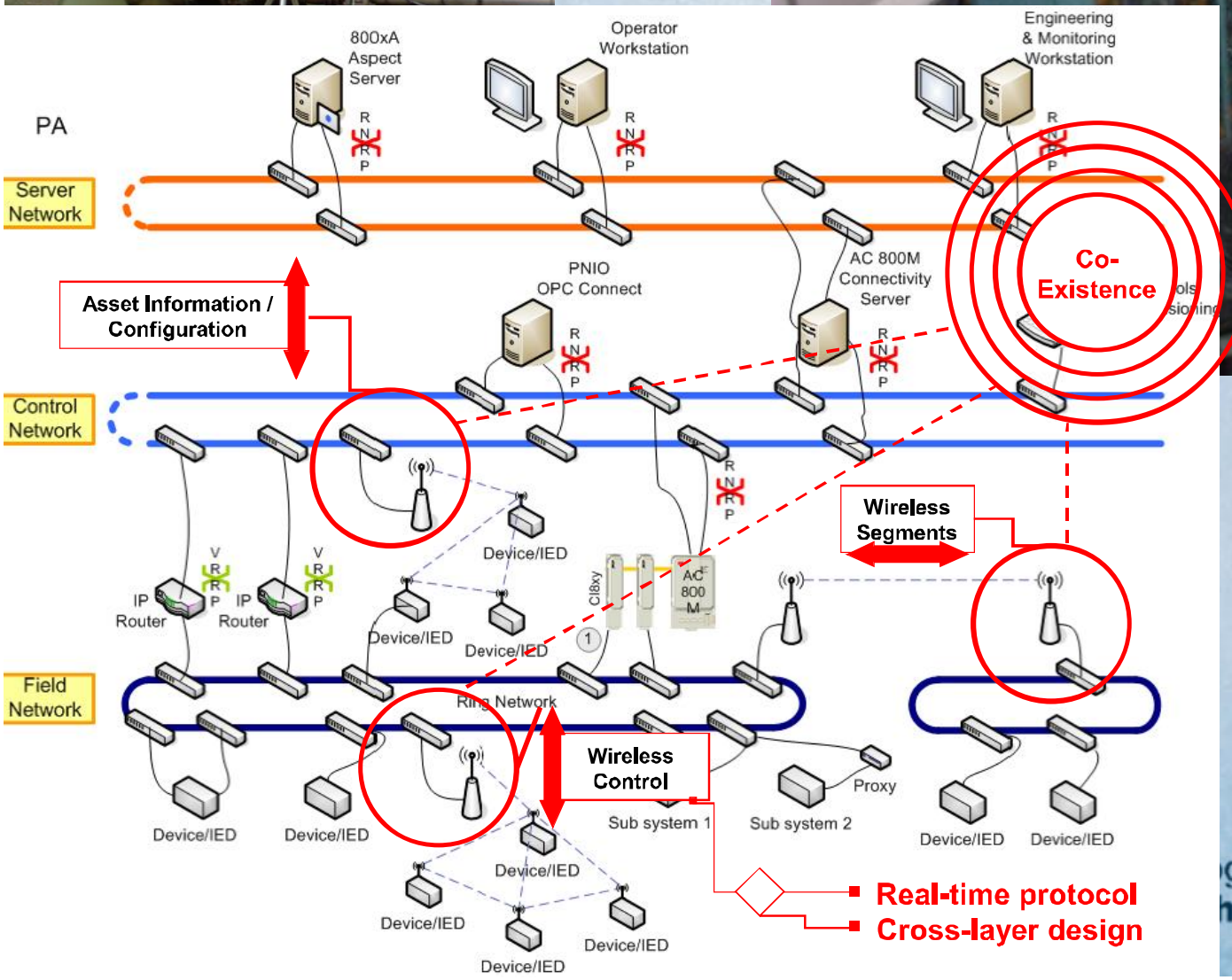
EISLAB
Luleå University of technology

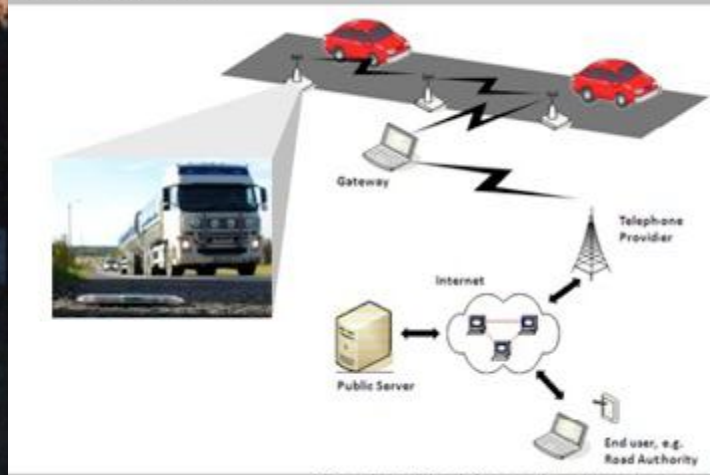
The northernmost University of Technology in Scandinavia
Top-class Research and Education



- 2,4 GHz
- FHSS
- DSSS
- Range
- Blacklisting
- ….

gy in Scandinavia
h and Education

Demonstrator setup

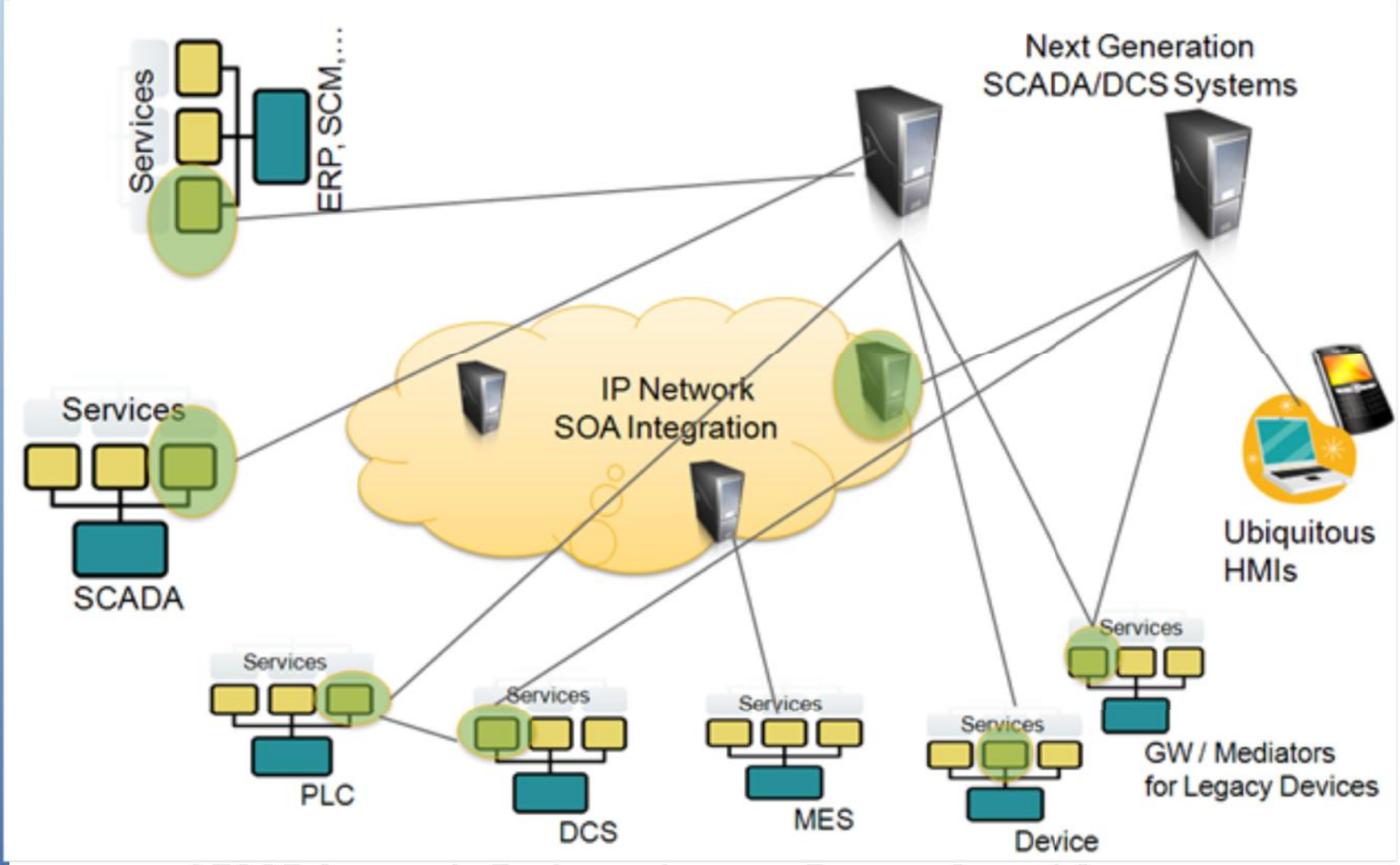


iRoad
www.iroad.se

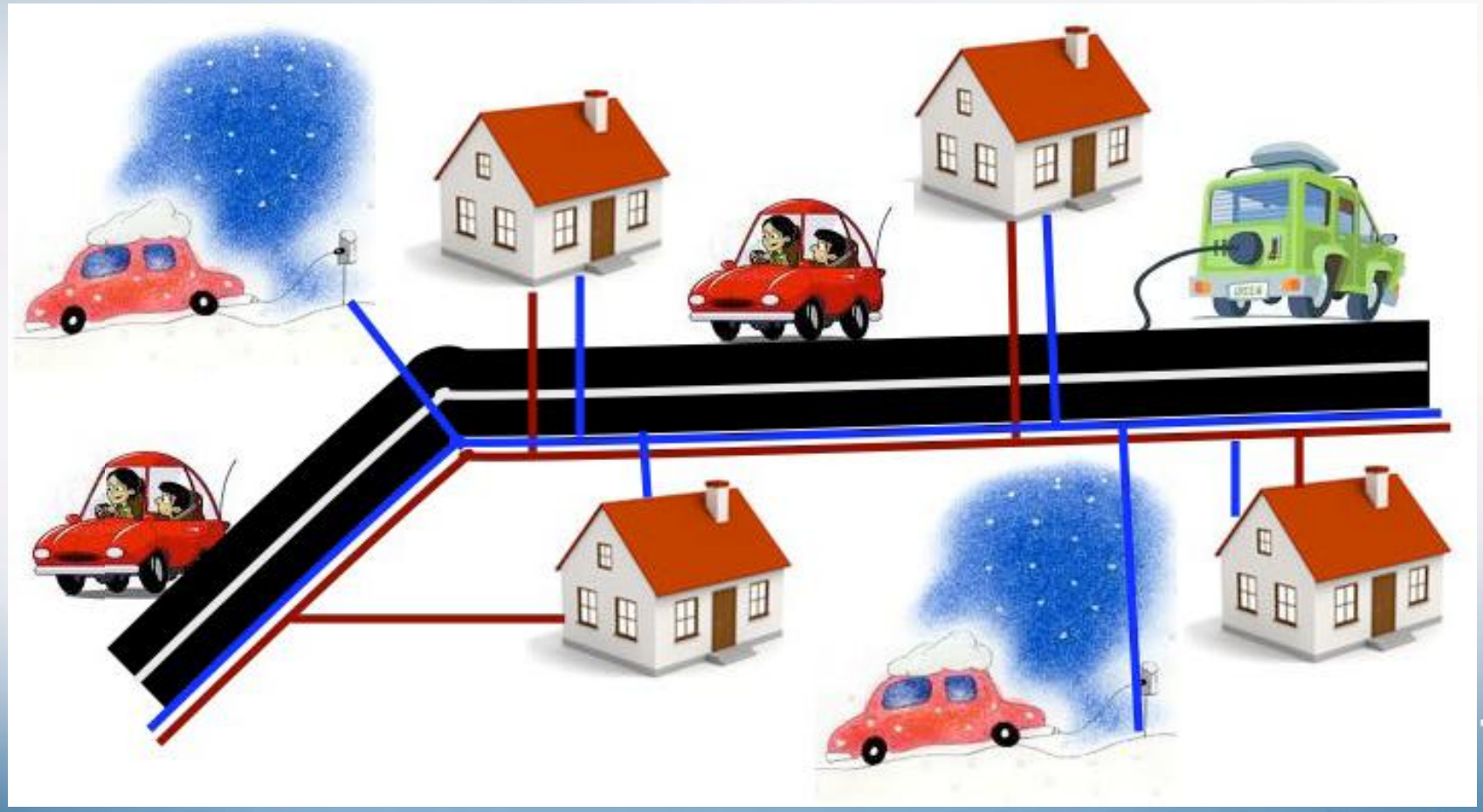
iRoad-Demo: Live Traffic Monitoring using a Road Marking Unit

The road marking unit is 7mm high and fully integrated with sensors, processor, solar cell, battery and radio communications unit. It is attached to the road surface with glue

The AESOP project



AESOP Approach: Far beyond current Process Control Systems
Towards a "Distributed Dynamically Collaborative" System of Systems



Maier identified the defining characteristics of a System of Systems*

SoS Characteristics	Mission Module Charateristics
Managerial Independence of Elements	Many mission systems are independent programs of record
Evolutionary Development	Mission modules will be developed in evolutionary increments
Emergent Behavior	Mission systems work together to provide capability (e.g., sensor mission systems provide targeting data for weapon mission systems)
Geographical Distribution of Elements	Mission Modules contain multiple vehicles that deploy from the LCS
Operational Independence of Elements	Mission Modules are composed of independent mission systems, each of which could be used independently

*Source: Maier, M.W., "Architecting Principles for System of Systems," Systems Engineering, Vol. 1, No. 4, 1998, pp. 267-284

Definitions

Linking systems into joint system of systems allows for the interoperability and synergism of Command, Control, Computers, Communications, and Information (C4I) and Intelligence, Surveillance and Reconnaissance (ISR) Systems:[1] *description in the field of information superiority in modern military.*

1. System of systems are large-scale concurrent and distributed systems the components of which are complex systems themselves:[2] *description in the field of communicating structures and information systems in private enterprise.*
2. System of systems education involves the integration of systems into system of systems that ultimately contribute to evolution of the social infrastructure:[3] *description in the field of education of engineers on the importance of systems and their integration.*
3. System of systems integration is a method to pursue development, integration, interoperability, and optimization of systems to enhance performance in future battlefield scenarios:[4] *description in the field of information intensive systems integration in the military.*

1. Manthorpe Jr., W.H., "The Emerging Joint System-of-Systems: A Systems Engineering Challenge and Opportunity for APL," Johns Hopkins APL Technical Digest, Vol. 17, No. 3 (1996), pp. 305–310.
2. Kotov, V. "Systems-of-Systems as Communicating Structures," Hewlett Packard Computer Systems Laboratory Paper HPL-97-124, (1997), pp. 1–15.
3. Luskasik, S.J. "Systems, Systems-of-Systems, and the Education of Engineers," Artificial Intelligence for Engineering Design, Analysis, and Manufacturing, Vol. 12, No. 1 (1998), pp. 55-60.
4. Pei, R.S., "Systems-of-Systems Integration (SoSI) – A Smart Way of Acquiring Army C4I2WS Systems," Proceedings of the Summer Computer Simulation Conference, (2000), pp. 574-579.

Definitions

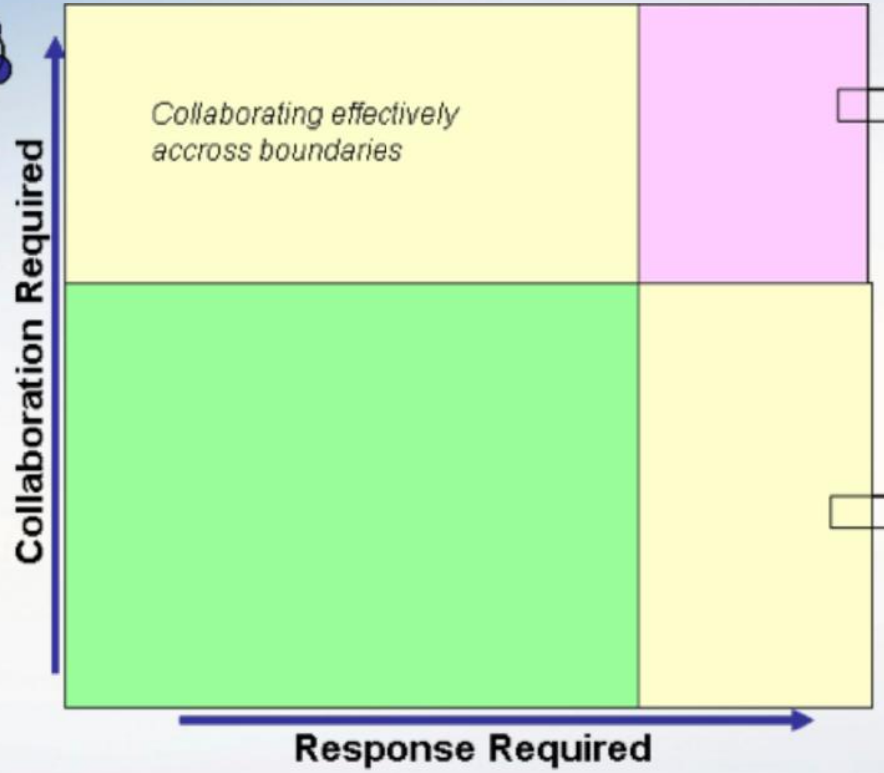
5. Modern systems that comprise system of systems problems are not monolithic, rather they have five common characteristics: operational independence of the individual systems, managerial independence of the systems, geographical distribution, emergent behavior and evolutionary development:[5] *description in the field of evolutionary acquisition of complex adaptive systems in the military*.
6. Enterprise systems of systems engineering is focused on coupling traditional systems engineering activities with enterprise activities of strategic planning and investment analysis:[6] *description in the field of information intensive systems in private enterprise*.
7. System of systems problems are a collection of trans-domain networks of heterogeneous systems that are likely to exhibit operational and managerial independence, geographical distribution, and emergent and evolutionary behaviors that would not be apparent if the systems and their interactions are modeled separately[7]: *description in the field of National Transportation System, Integrated Military and Space Exploration*.

5. Sage, A.P., and C.D. Cuppan. "On the Systems Engineering and Management of Systems of Systems and Federations of Systems," Information, Knowledge, Systems Management, Vol. 2, No. 4, 2001, pp. 325-345.
6. Carlock, P.G., and R.E. Fenton. "System-of-Systems (SoS) Enterprise Systems for Information-Intensive Organizations," Systems Engineering, Vol. 4, No. 4 (2001), pp. 242-261.
7. DeLaurentis, D. "Understanding Transportation as a System of Systems Design Problem," 43rd AIAA Aerospace Sciences Meeting, Reno, Nevada, January 10-13, 2005. AIAA-2005-0123.
DeLaurentis, D. A. and Callaway, R. K. "A System of Systems Perspective for Future Public Policy," Review of Policy Research, Vol. 21, No. 6, 2004. pp. 829-837.

The Double Challenge and SoS Characteristics

- Degree of Centralization
- Stakeholder Diversity

- Operational Independence
- Diversity of Constituents



- Independent Evolution of Constituents
- Changing Demand
- Volatility of Structure
- Predictability of Quality Attributes
- Range of Capability Provided
- Evolution of SoS

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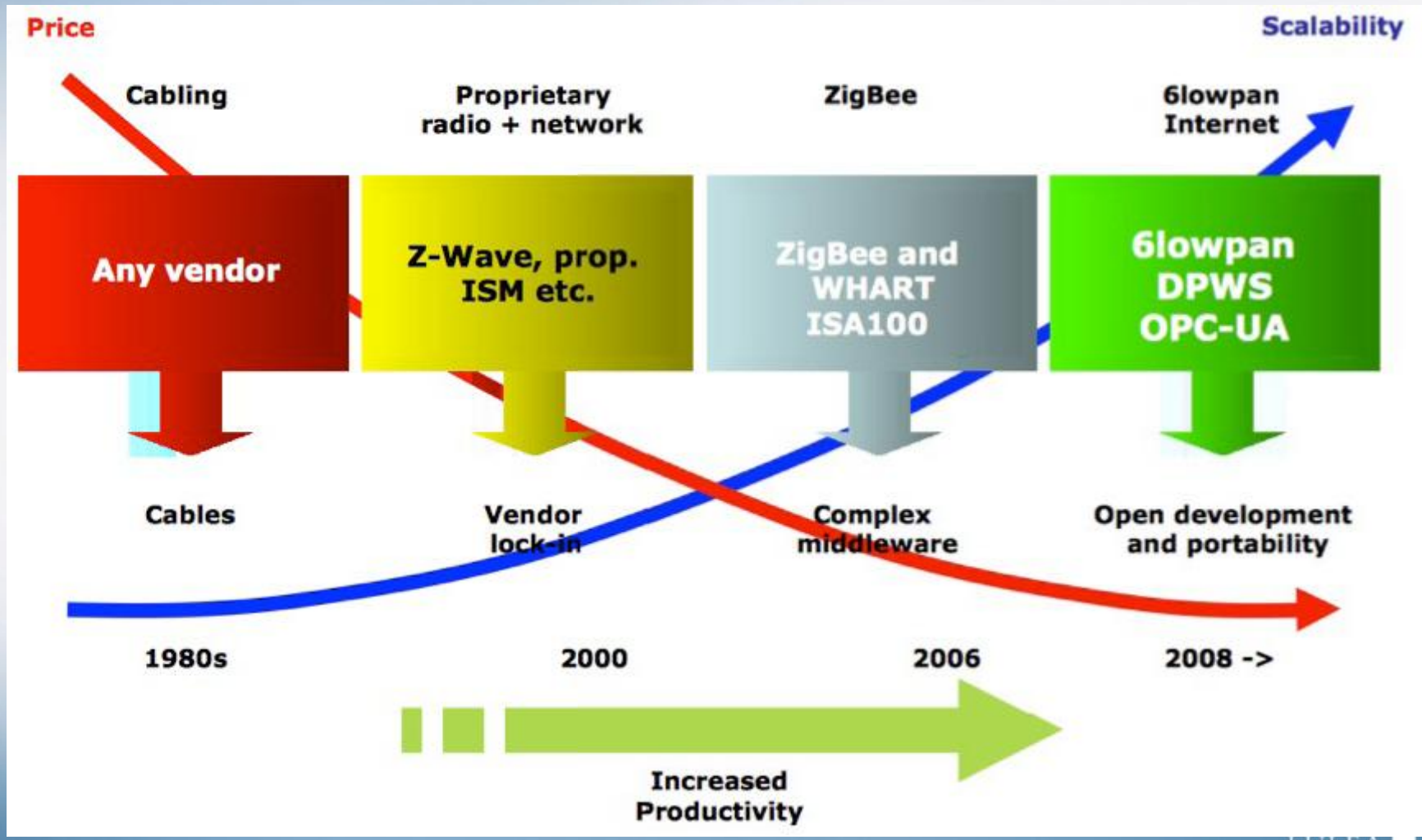
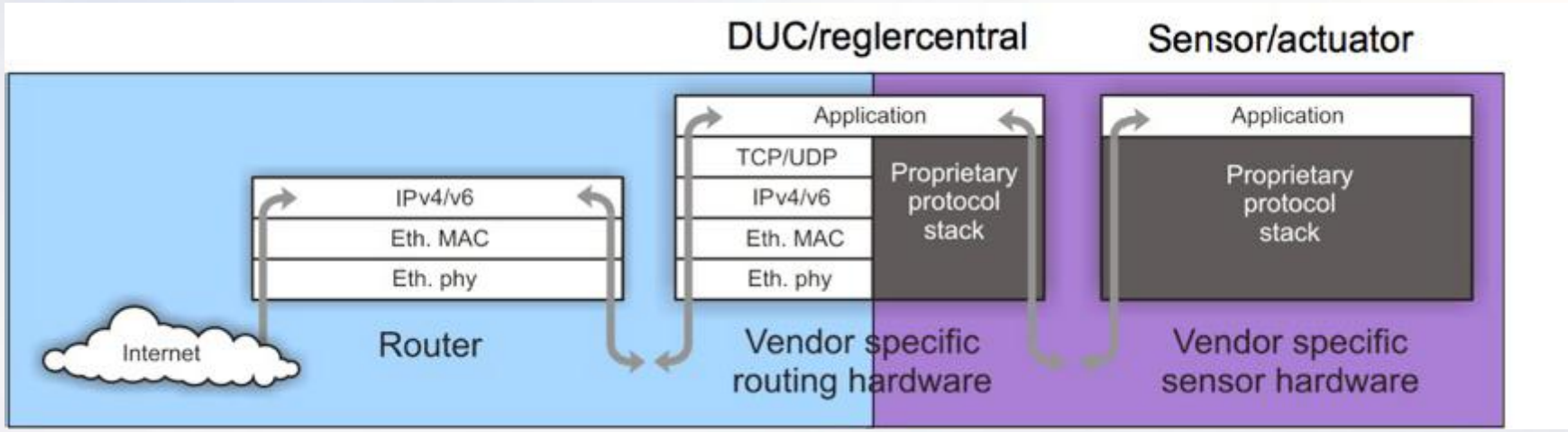
What about technology then

- From where are we coming
- Where are we going

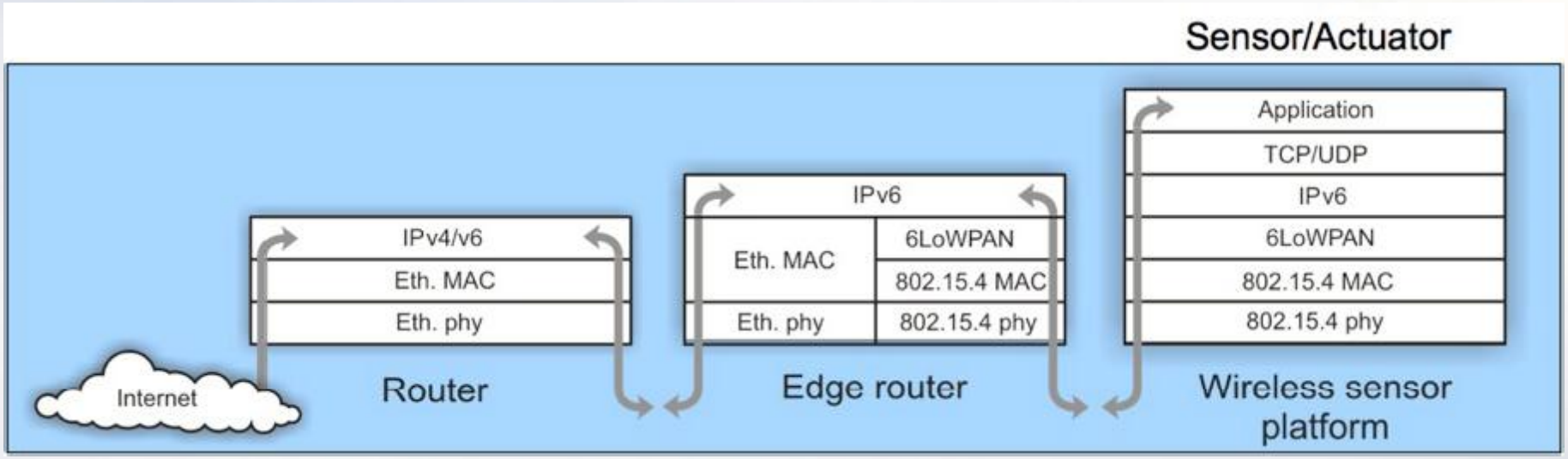
Wireless Sensor Networks



Communication paradigm



Internet -> device/sensor level



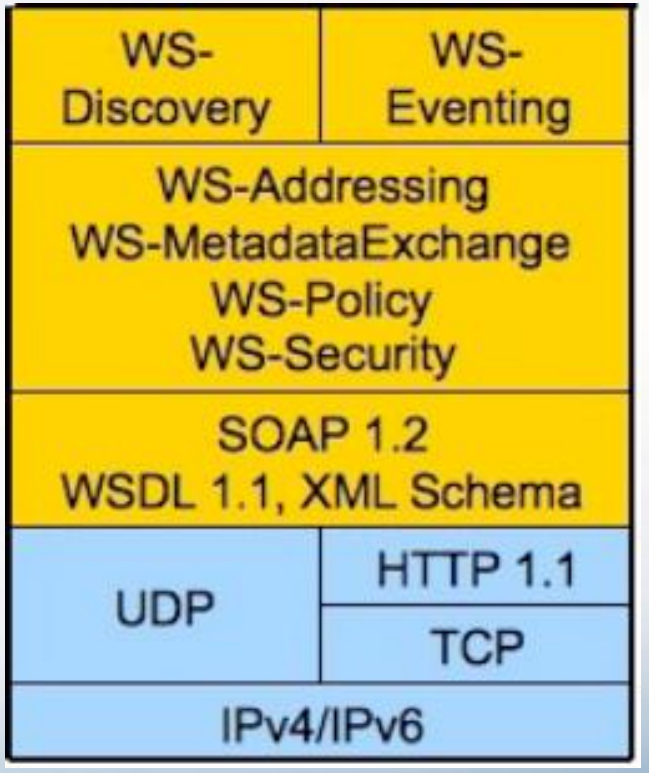
The application level SOA on devices

Large EU projects

- SODA
- Socrades
- AESOP

Targeting

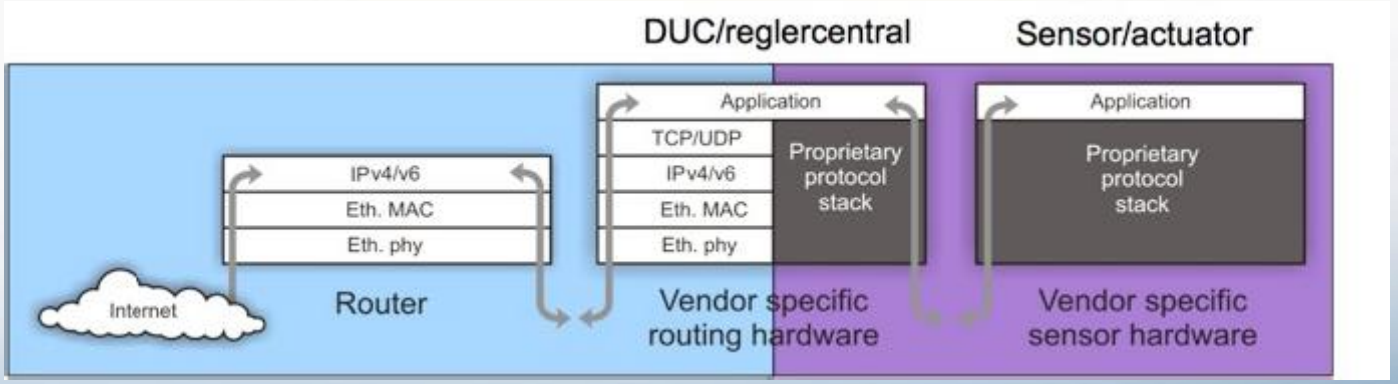
- Very large system control
  - Manufacturing
  - Process industries



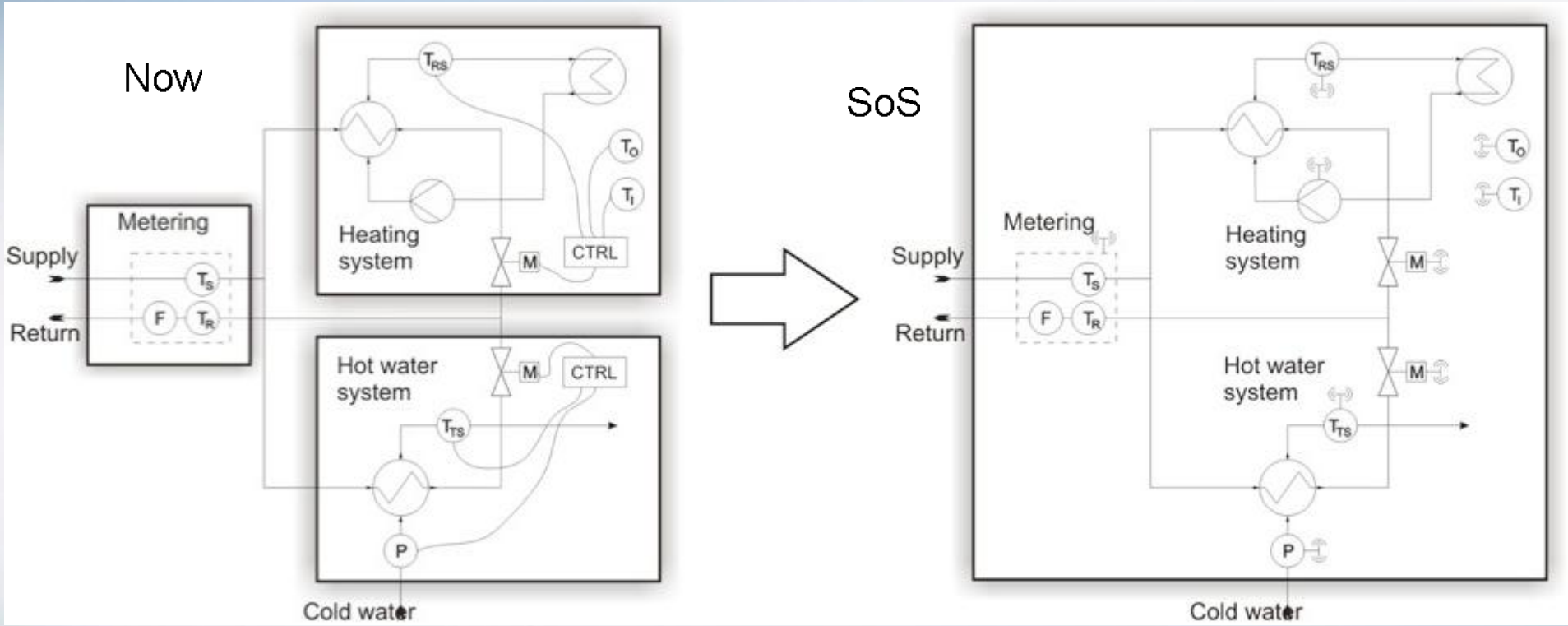
Real world example

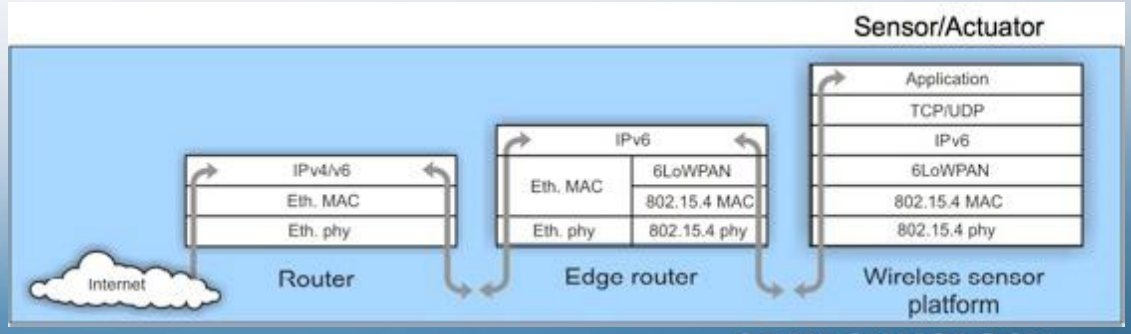
Airport security

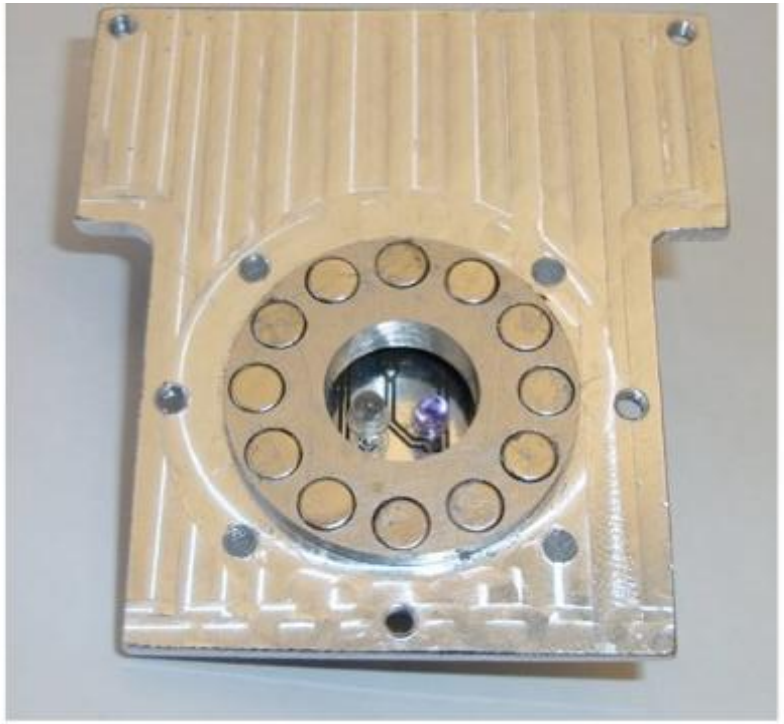
- Arlanda
- SOA integrates a large number of surveillance equipment
  - at gateway/mediator level
- SAABGroup



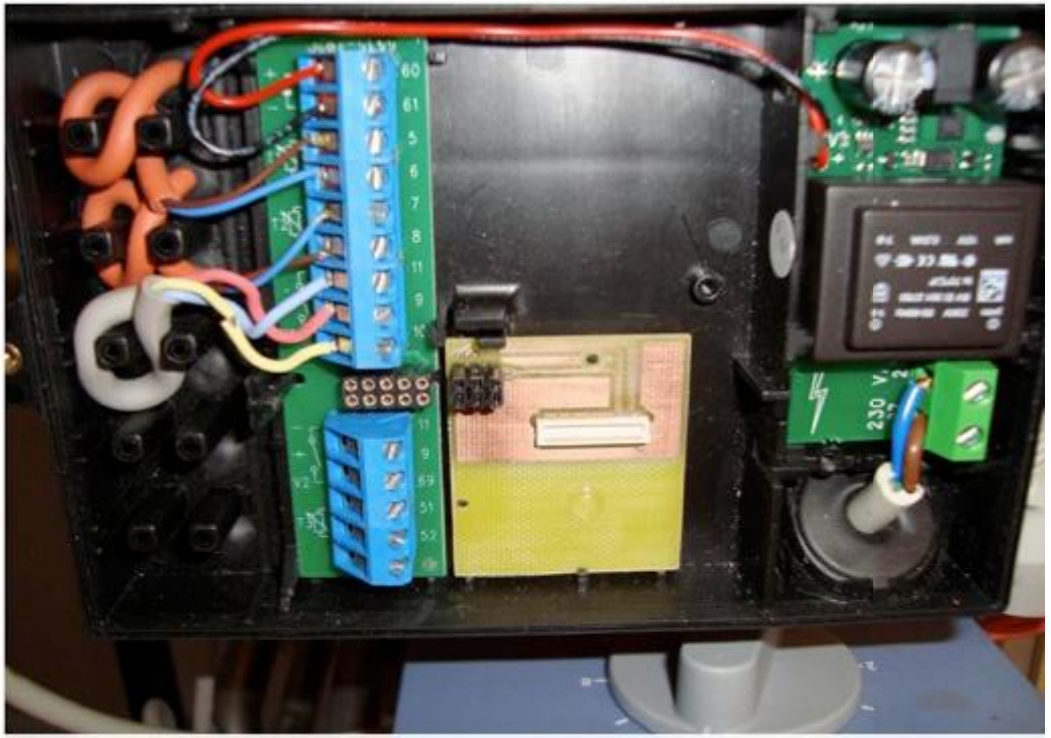
System of systems integration district heating application








MULTICAL® 601
strup

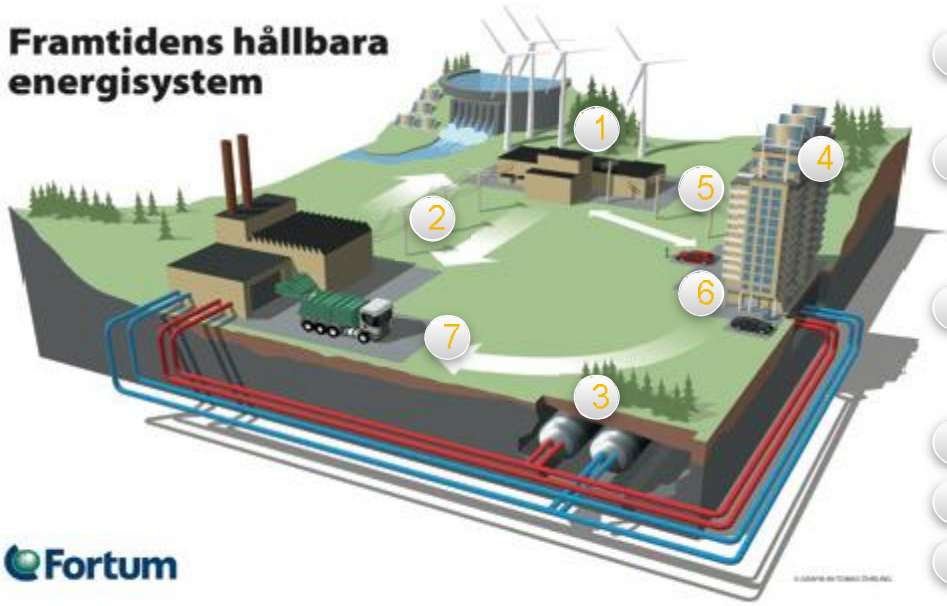


Real word example

Customer and group information viewing interface

http://sm-pc777.sm.ltu.se/distheat/

Smart värme – ett forskningsprojekt för framtidens hållbara energisystem



El, värme, kyla, och gas i ett enda integrerat system där man alltid tar tillvara på överskottsenergi

Vi tar tillvara på energi som annars skulle gå förlorad, och använder den när den behövs.

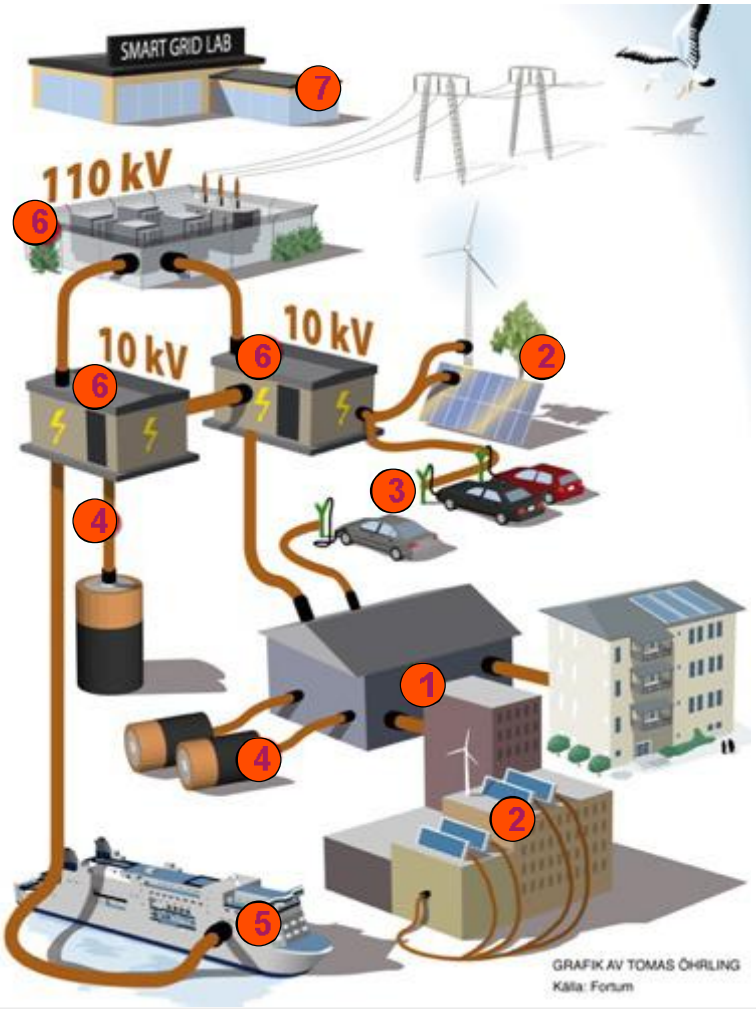
1. Sol och vind leder till stora variationer i elproduktionen. Behovet av reglering blir större ju mer förnybart som byggs.
2. Om det finns el i överskott, omvandlas den elen till värme och sparas. Värmen kan sedan användas när den behövs. El produceras också i kraftvärmeverken. Då bildas samtidigt värme, och om den är i överskott lagras den till senare.
3. I stora värme/kylalager sparas värmen eller kylan till dess den behövs. Det vill säga att en kall vinterdag kan vi värma staden med den energi som vi sparat sedan den togs tillvara en solig sommardag.
4. Bostäder i staden ska kunna producera både el och värme lokalt.
5. Smarta elnät gör det möjligt att jämna ut elförbrukningen och anpassa den till elproduktionen.
6. Genom att laddinfrastrukturen för elbilar också integreras i energisystemet kan bilarnas batterier fungera som små energilager. En utbyggnad av biogasen tillgodoser hela transportsidans behov av energi.

Vi tar tillvara på all energi som finns lokalt

7. Lokala kretslopp möjliggör att hushållsavfall blir till el, värme, och biogas i systemet. Tillsammans leder det här till minskade utsläpp.

Fortum

Fortum och ABB med flera driver en storskalig FoU-satsning för framtidens hållbara elsystem i Norra Djurgårdsstaden



1. Aktiva hus och efterfrågestyrning
2. Distribuerad lokal energiproduktion
3. Användning av elfordon och smart laddning
4. Energilager som stöd för kunder och nät
5. Smart elektrifierad hamn
6. Smarta nätstationer
7. Center för drift, forskning och uppföljning

ABB

Fortum

Wrap and reuse instead of rip and replace

SOA

- Low level component delivers a service.
- High level services are created as combinations of lower level services
- New services and functionalities are developed over time
- Not all functionalities are know today
- New services are developed based on demand and innovation

AESOP - Architectural Components (WiP)

- Discovery (location, device identification, to-app integration service)
- Device/System Repository
- Security (policy, enforcer, auxiliary services …)
- Infrastructure Capabilities (Topology, connectivity, QoS, diagnostics …)
- Service lifecycle management
- service repository (capabilities, code/implementation, semantics etc.)
- service matching
- service evaluation
- service migration
- Service composition/orchestration
- load balancing
- monitoring (KPI based e.g. load, topology, link connection, real-time, health etc.)
- resource management (reservation QoS etc.)
- Eventing (filtering, processing, etc.)
- Gateway / Service Mediator
- Business Process Execution
- Communication Manager (location/protocol aware)
- Historian
- Alarms/Notifications
- Configuration management
- TestSuite (detection of information drain, service simulation / feasibility assessment)
- Risk analysis (dependencies, impact, change management…)
- Runtime management (stability, real-time,
- Ontology (Concelator=translation e.g. for exchange of devices)

SoS technologies

- COTS based HW
- SOA
  - DPWS
  - OPC-UA
- Agents
- Ontologies
  - SensorML
  - ControlML
  - ....XML

System integration not seamless

- A jungle of service standards and “languages”
  - Electricity
  - District heating
  - Control system
  - Traffic
  - Cars
  - Mining
  - Pulp & Paper
  - ..
  - ..

Challenges

Systems compatibility

Systems discoverability

Systems localization

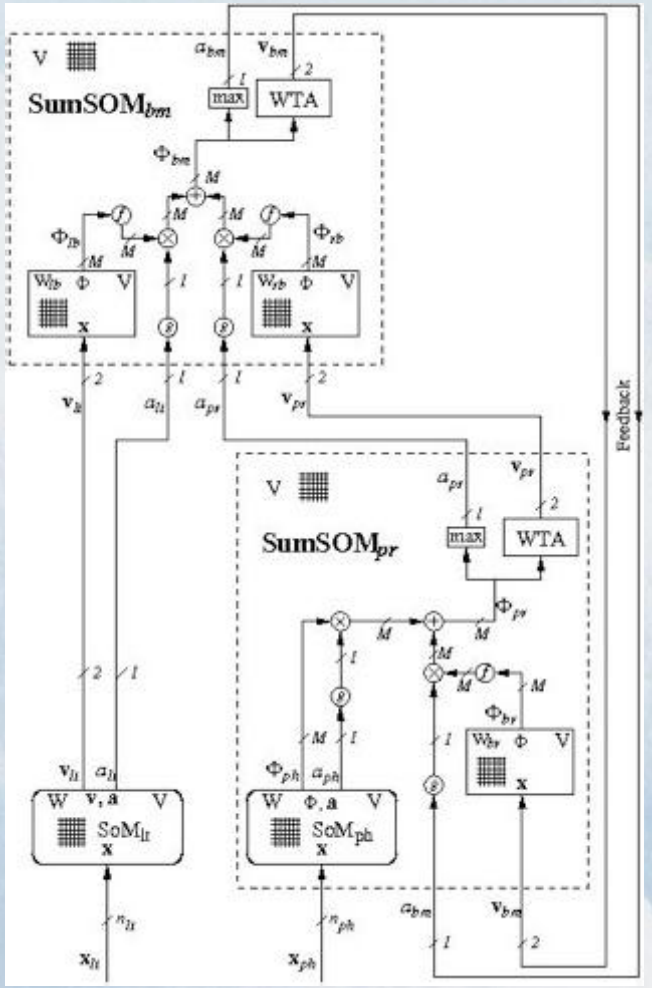
System evolution

System security

System stability

Enabling self organizing “thinking” systems

- Using human like technology



- Biology
  - Neuron
  - Neuron firing
  - Lower “brain” functionality
  - Cortex
  - Immune system
- Human build
  - MULLE - silicon
  - TCP/IP communication
  - Hard coded sensor & actuating fusion
  - Self-organization with Feed-forward - Feedback
  - Secuirty

Summary

SoS -> opportunities for customers -> potential business

Challenges for vendors:

- Need to understand!
  - Role
  - Technology (HW) SW
  - Business model
- When to enter?

Thanks for listening