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The Internet of Things

- An Industrial Perspective -

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Consumer Benefits of Wireless Sensor Networks

Lifestyle:

Wireless sensors can enrich consumer experiences and can enable safety and privacy in the digital society

Consumer Benefits of Wireless Sensor Networks

Health:

Wireless body sensors enable pro-active healthcare

Consumer Benefits of Wireless Sensor Networks

Mobility:

Wireless sensors enable safer and more efficient driving

Consumer Benefits of Wireless Sensor Networks

Sustainability:

Wireless sensors enable better environmental conditions

Internet of Things

- Significantly more devices than current networks
- Severely limited code and ram space (e.g., highly desirable to fit the required code--MAC, IP and anything else needed to execute the embedded application-- in, for example, 32K of flash memory, using 8-bit microprocessors)
- Unobtrusive but very different user interface for configuration (e.g., using gestures or interactions involving the physical world)
- Robustness and simplicity in routing or network fabric

Overview

- Trends related to pervasive networking
  - Consumers
  - Economy
  - Applications
  - Technology
- Networking application requirements
  - Home
  - Health
  - Mobility
- Challenges of pervasive networks
  - Application
  - Network
  - Sensor nodes

Trends: European Consumers

- Individualization
- Mobility
- Lifestyle of Health and Sustainability
- Digital Society
  - E-Commerce
  - E-Health
  - E-Services, incl. E-Government

Trends: Economy

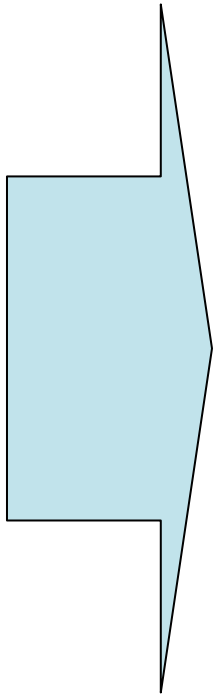
- Driven by high convenience services
- Consumer market transparency
- Anticipation of consumer needs
- Memetical war for consumer attention

Trends: New application paradigms

- Personal lifestyle management
  - Attention
  - Time
  - Involvement
  - Safety
  - Energy consumption
- Personal healthcare
  - Wellness and beauty
  - Fitness
  - Risks
  - Diseases
- Cooperative driving
  - Preventive safety
  - Driver-centric convenience

Trends: Technology Re-Defined

- Systems
- Passive Tags
- Information Internet
- High Tech
- Features & Options
- Always-On
- Exposure



- Software-based services
- Wireless sensors
- Experience Internet
- Trusted Tech
- Experienced Sense & Simplicity
- Always-Responsive
- Privacy

Networked Lifestyle Requirements

- Example: Light Management

- Requirements:
  - Adaptive lighting atmospheres
  - Wireless control of lighting atmosphere of entire buildings
  - System scalability
  - Network responsiveness
  - Security
  - Integration with light sources

Networked Health Requirements

- Example: Connected senior with multiple-diseases health risk

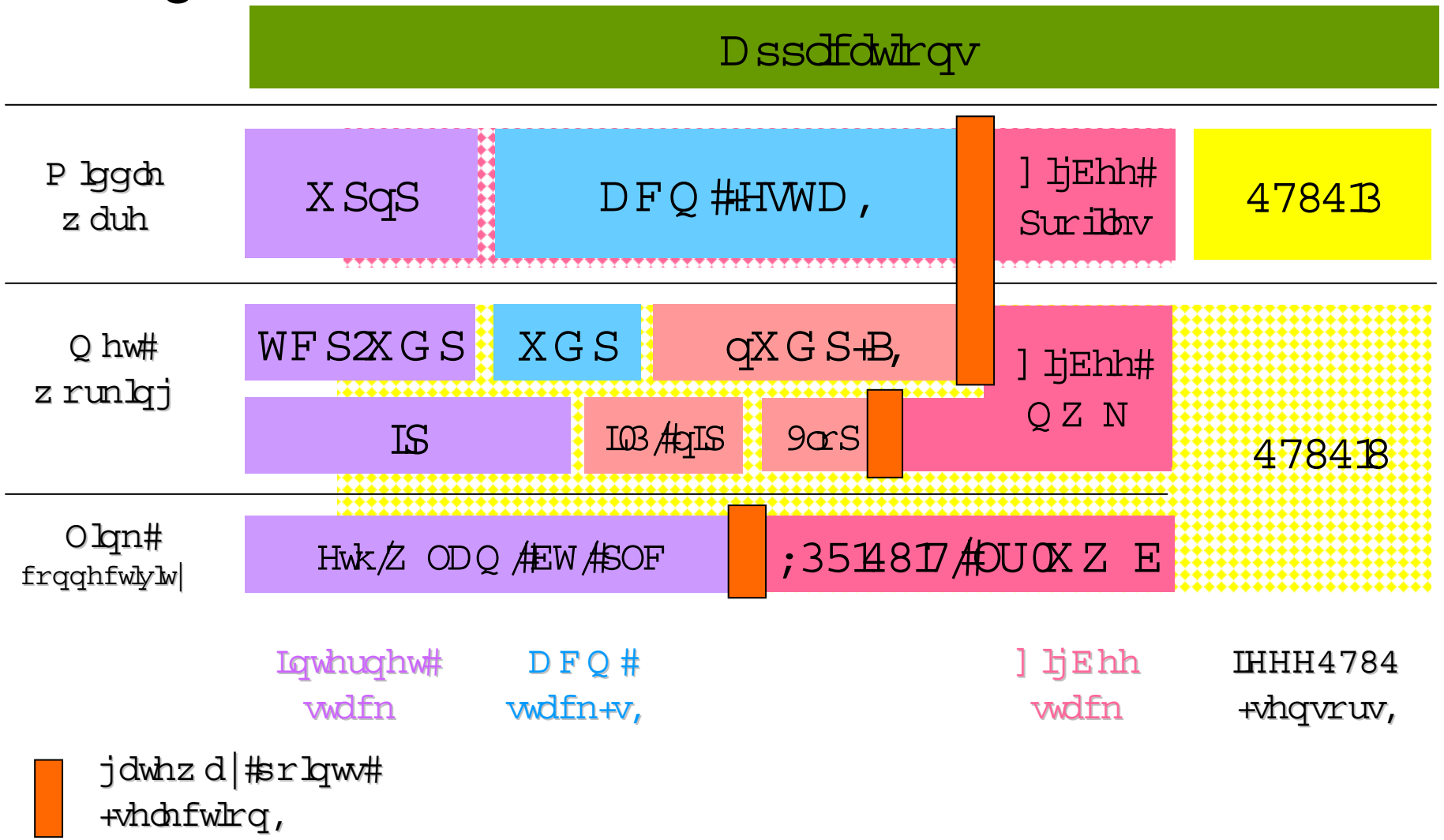
- Requirements:
  - Continuous monitoring of multiple vital parameters for preventive healthcare
  - Local signal processing and data fusion and storage
  - Best connect wireless networking across BAN, PAN, LAN, WAN
  - Agile radio
  - Application robustness with respect to radio interference
  - Location awareness
  - Ultra low power
  - Wearable
  - Privacy and security

Networked Car Requirements

- Example: Cooperative driver

- Requirements:
  - Monitoring of driver condition with ambient electronics , e.g. stress and drowsiness
  - Traffic monitoring for preventive safety, incl.
    - car-to-car
    - car-to-roadsite communication
    - cooperative sensing
  - Security and privacy of car/driver information

Challenge: Interoperability in the Internet of Things



Research Agenda: Marriage of Internet and Control

- IP adaptation/Packet Formats and interoperability
- Addressing schemes and address management
- Network management
- Routing in dynamically adaptive topologies
- Security, including set-up and maintenance
- Application programming interface
- Discovery (of devices, of services, etc)
- Implementation considerations
  - Gateway or all-IP (e.g. 6lowpan)

Application-Driven Challenge: Distribution of Intelligence

Scalability problem:

– As the number of sensors grows, network and server get overloaded

Possible solution:

– Distribute application processing

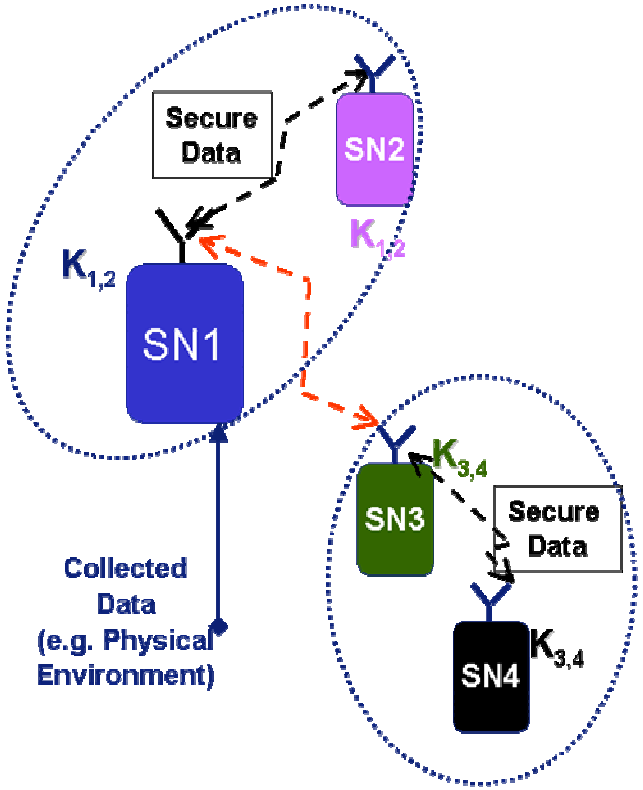
– Move aggregation and filtering functions (data fusion) to the network edge

– Code distribution and management

Application-Driven Challenge: Security in Autonomous WSN

- **Problem: Absence of security infrastructure**
  - **WSN security relies on autonomous sensors**
  - **no centralized online certification authorities**
  - **no previous trust**

- **Challenges**
  - **Security models (appropriate for each application)**
    - **Previous trust, no previous trust**
  - **Secure group formation and management**
    - **Location context**
    - **Efficient and resilient group management**
  - **Key distribution (static and dynamic)**
    - **Server-based, Pre-distribution (Random, Deterministic)**



Networking Challenge: Self-Organizing Networks

Objective

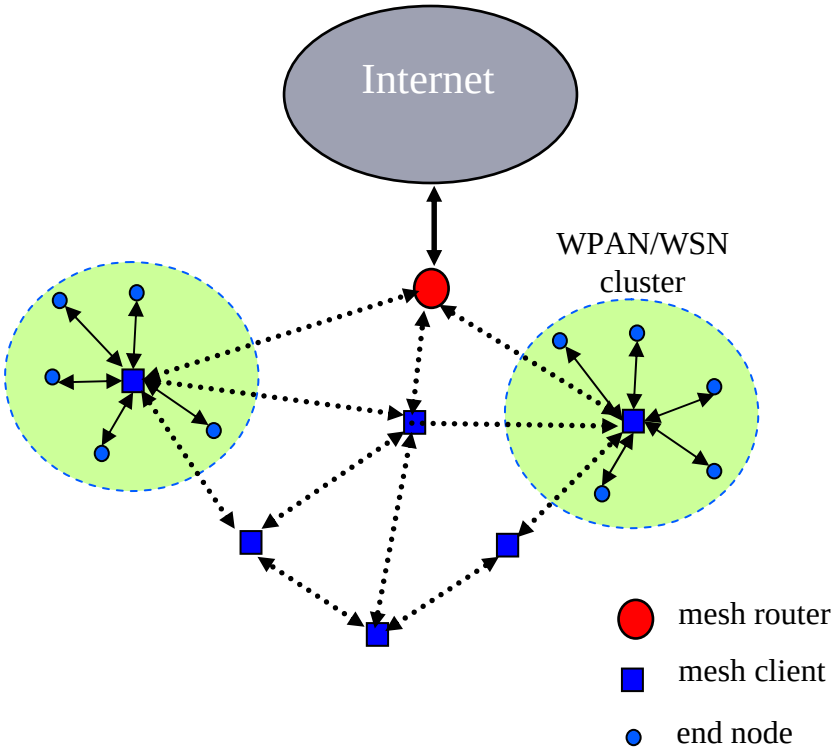
- Wireless multi-hop network with short range and very low-cost devices to cover a large area

Mesh Network Advantages

- extends network coverage without increasing
  - TX power / RX sensitivity
  - less interference
- enhances transmission reliability via multiple routes
- self-configuration of network
- dynamically adapts to changing environment
- long battery life time

Mesh Network Challenges

- ad-hoc networking with mobility support
- distributed vs. centralized control
- cross layer design: MAC / network layer
- scalability
- QoS support for delay sensitive applications
- power efficiency

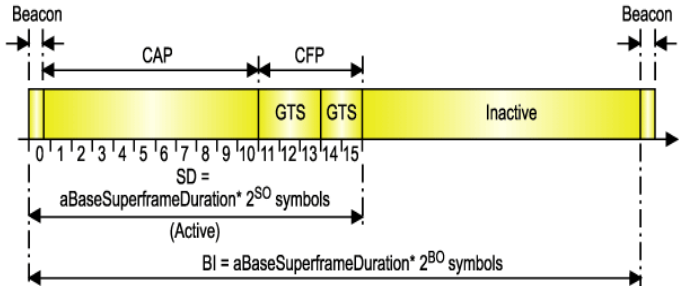


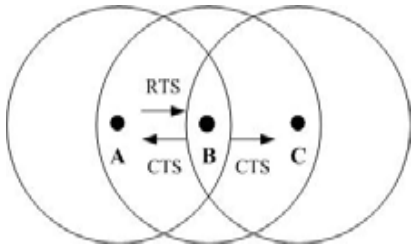
Applications / Usage Scenarios

- home/building automation
- asset management
- monitoring and control

Networking Challenge: Limitations of wireless networks

- **Robustness**
  - ! Interference with other RF networks operating in same frequency band
    - ➢ Interference mitigation mechanisms
- **Real-time communication**
  - ! No sufficient QoS support
    - ➢ Multi-hop GTS mechanism
- **Reliability**
  - ! Hidden terminal problem
    - ➢ Design virtual handshake mechanism
  - ! Systematic collisions possible
    - ➢ Improved randomized back-off algorithm
- **Stack size**
  - ! ZigBee stack (>48KB) too complex for tiny sensors
    - ➢ ZigBee “light”





Additional Challenges

- Application challenges
  - Data mining algorithms
  - Time-line for the future of WSNs and applications
  - Value creation and business models for new applications
- Network challenges
  - Light-weight protocols and middleware scalability
  - Robustness in dirty contexts
  - Availability
- Challenges for wireless sensor nodes
  - Dirty radio technology
  - Energy scavenging devices
  - From nodes to SAND to dust