Application Lecture 3: Multimedia Sensor Networks

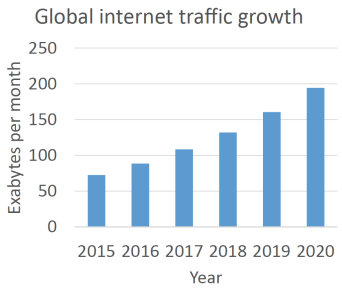
7COM1030 – Multicast and Multimedia Networking

Dr. Xianhui Che (Cherry)
x.che@herts.ac.uk
School of Computer Science
University of Hertfordshire, UK

University of Hertfordshire UH

Trend of Internet Traffic

Supply vs. Demand



- Compound annual growth rate of 23% (Cisco 2016). Expected to saturate the lit fibre network by 2020

Mobile network

- In 2015, wired devices accounted for 52% of the IP traffic
- By 2020, wireless and mobile devices will take up 66% of the IP traffic

Content

- Internet video (82% of the IP traffic by 2020)
- Virtual reality (x4 in 2015)
- Internet gaming (x7 in 2015)

Future network research in light of the challenges:

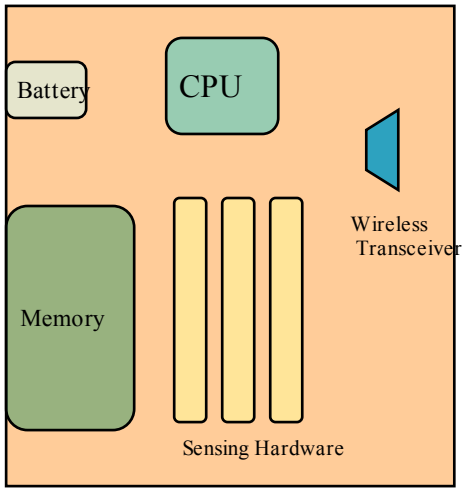
- Growing demand for internet capacity
- Hybrid, converged network consisting of wired and wireless networks, backbones and access networks
- Demanding user Internet content- latency and QOS issues
- Research collaboration is essential

Statistics from NDFIS – National Dark Fibre Infrastructure Service

Topics

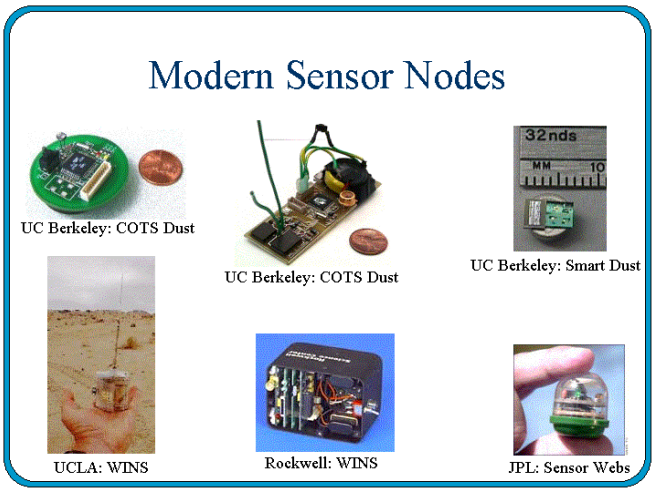
- Traditional Wireless Sensor Networks
- Wireless Multimedia Sensor Networks

Sensor Node



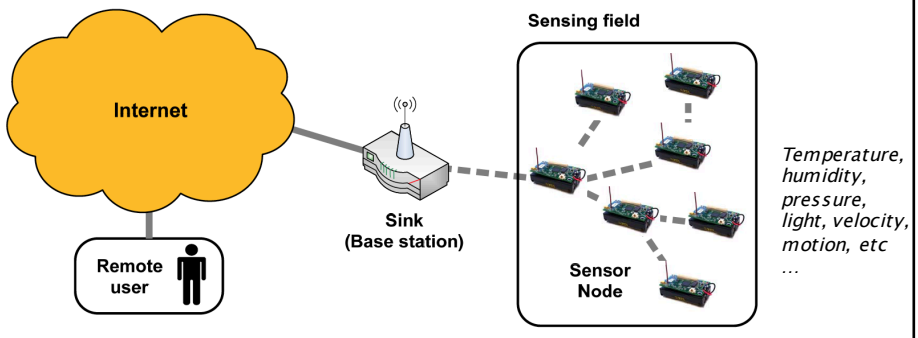
- Sensors
  - Integrated Wireless Transceiver
  - Limited in
    - Energy
    - Computation
    - Storage
    - Transmission range
    - Bandwidth

Sensor Examples



Wireless Sensor Networks

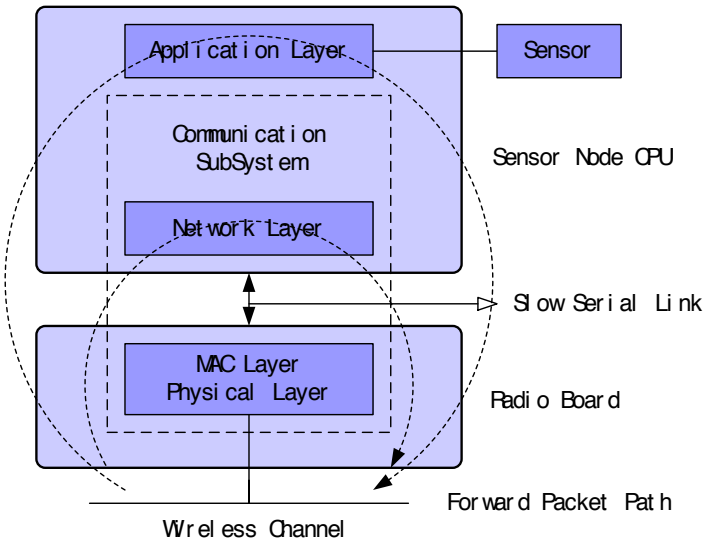
- Wireless Sensor Networks (WSN) combines technologies of sensing, computation, and wireless communication, in order for us to understand, serve, and control the physical world.



Characteristics of WSNs

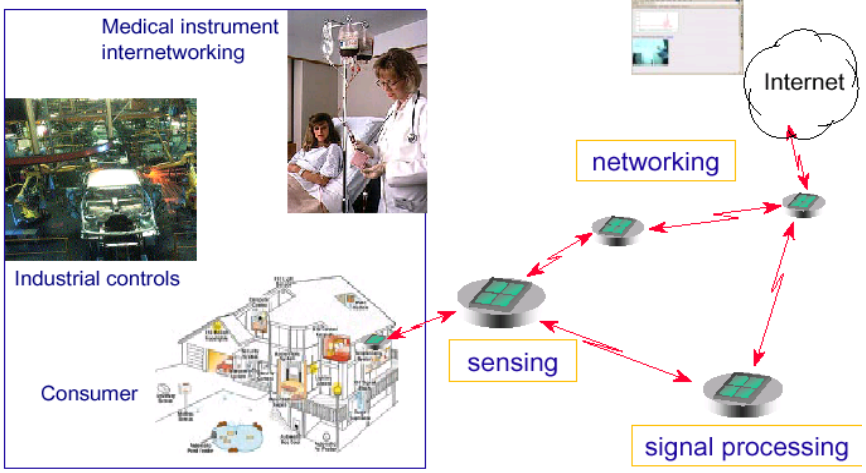
- **Deeply distributed architecture:** localized coordination to reach entire system goals, no infrastructure with no central control support
- **Autonomous operation:** self-organization, self-configuration, adaptation, exception-free
- **Energy conservation:** physical, MAC, link, route, application
- **Scalability:** scale with node density, number and kinds of networks
- **Data centric network:** address free route, named data, reinforcement-based adaptation, in-network data aggregation

Overall Architecture of a Sensor Node



Application Examples

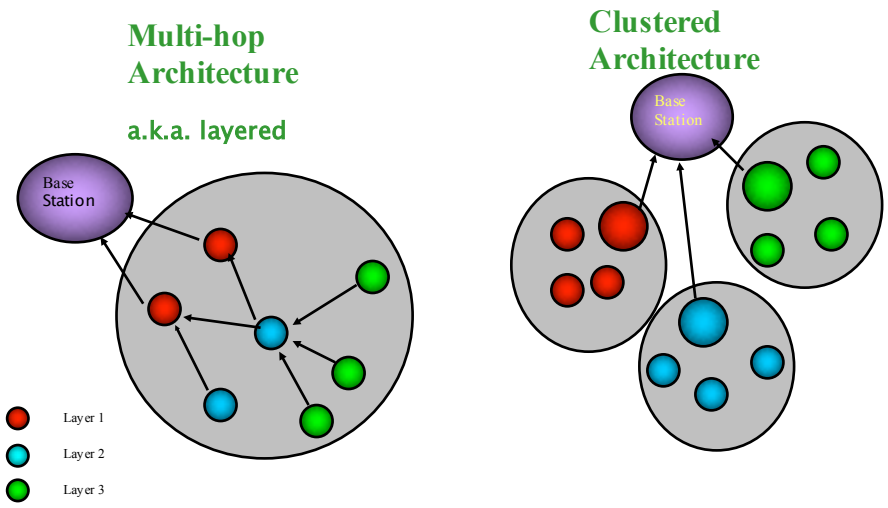
- Low-power Networking



Design Challenges of WSNs

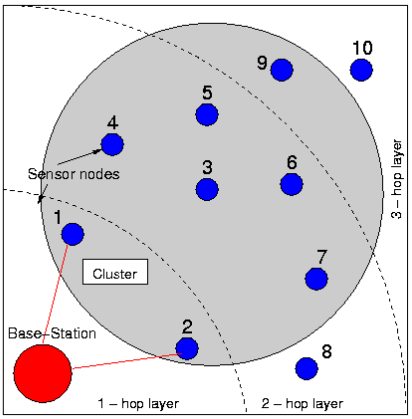
- **Challenges**
  - Limited battery power
  - Limited storage and computation
  - Lower bandwidth and high error rates
  - Scalability to 1000s of nodes
- **Network Protocol Design Goals**
  - Operate in self-configured mode (no infrastructure network support)
  - Limit memory footprint of protocols
  - Limit computation needs of protocols -> simple, yet efficient protocols
  - Conserve battery power in all ways possible
  - Take physical transmission limitations into account

Network Architectures



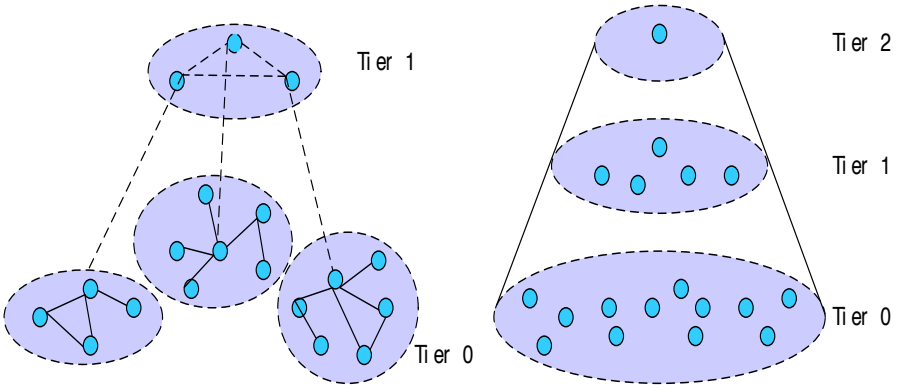
Multi-hop Network Architecture

- Wireless Multi-Hop Infrastructure Network Architecture
- A few hundred sensor nodes (half/full duplex)
- A single powerful base-station
- Network nodes are organized into concentric ***Layers***
- ***Layer:*** Set of nodes that have the same hop-count to the base-station
- Additional Mobile Nodes traversing the network



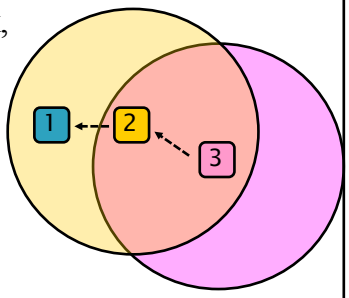
Clustered Network Architecture

- Sensor nodes autonomously form a group called clusters.
- The clustering process is applied recursively to form a hierarchy of clusters.



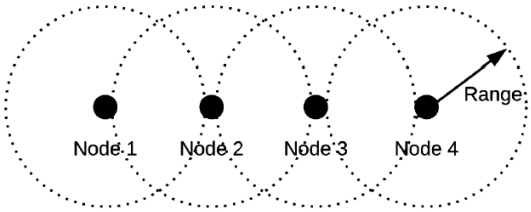
"Topology" for Wireless/Mobile Network

- It would be inaccurate to use the term "Topology" in wireless or mobile network, as the transmission of wireless/mobile signals is **broadcast** – the only factor that makes a difference to the structure of a wireless/mobile network is whether certain nodes are in or out of range.
- Note that "Wireless" and "Mobile" are two different terms in the engineering field.
  - Wireless network mostly refers to high speed network connection in local areas and focuses more on data, e.g. WiFi
  - Mobile network focuses more on the portability and mobility aspects, e.g. 3G mobile phone



Wireless "Topology" Example

Design stage →



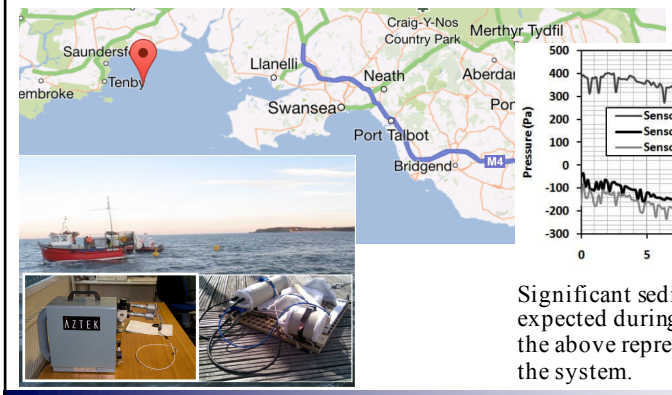
In reality, it may look like this →

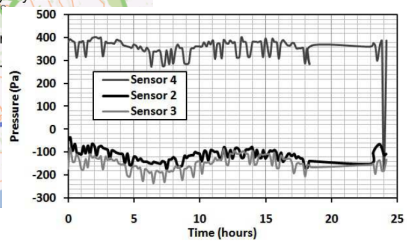
WSN for Industrial Purposes

- Traditional WSNs are normally designed and implemented for a specific set of applications.
  - The choice of operating frequency, bit rate, and antenna design, requires careful deliberation during the design phase.
- There is no universal solution for communication protocol.
  - Each solution has to uniquely balance parameters such as packet length, traffic pattern, duty cycle, in order to achieve an optimized solution for the specific application.
- The protocol design should maintain as much flexibility as possible because of the many unknowns in the possibly hostile deployment environment.

Case Study

- Automated Sensing Technologies for Coastal Monitoring (ASTEC) is an 0.4 million GBP project, funded by Technology Strategy Board (TSB), which aimed to deploy a novel marine sensor network on the sea bed to enable the gathering of data and to consequently quantify the effects of coastal erosion beneath the sea surface, a.k.a. depth of closure.





Significant sediment movements were not expected during the 24 hours trial and thus the above represents the sensitivity level of the system.

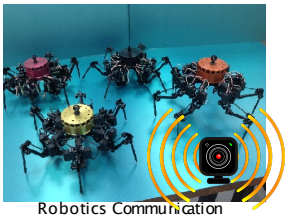
Topics

- Traditional Wireless Sensor Networks
- Wireless Multimedia Sensor Networks

Wireless Multimedia Sensor Networks

- Traditional sensor networks carry data quantity in the order of bytes that normally contain meter-reading information such as temperature, pressure, humidity, on/off.
- WMSN aims to bring sensors closer to end users, embracing rich data content such as image, audio, or even video. There is a tremendous diversity of applications:


Surveillance Network


Robotics Communication

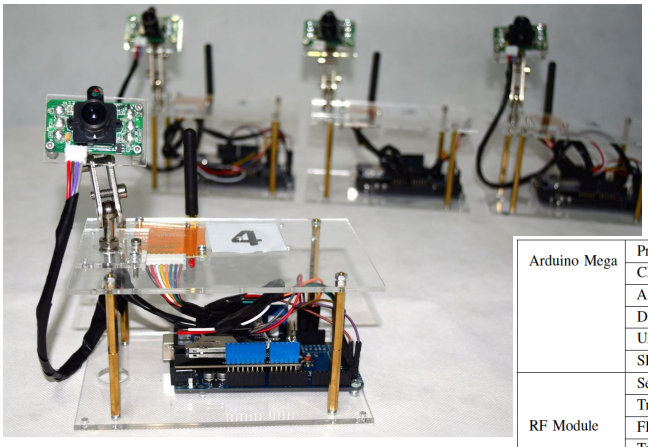

Activity Storage


Traffic Avoidance and Control


Healthcare and Homecare


Industrial Process Control

Image Sensor Node Prototype



- License-free ISM band 433MHz is used as the RF frequency.
  - Low probability of interference
  - Potential for long transmission range

Arduino Mega	Processor	ATmega2560
	CPU Speed	16 MHz
	Analogue I/O	16/0
	Digital I/O	54/15
	UART	4
	SRAM	8 KB
RF Module	Serial Port Data Rate	Up to 57,600 bps
	Transmission Data Rate	Up to 19,200 bps
	FIFO Buffer Size	Up to 256 bytes
	Transmission Power	Up to 20 dBm
	Modulation	GFSK
	Transmission Range	2000 meters (tested)
Image Sensor	Serial Camera	320×240

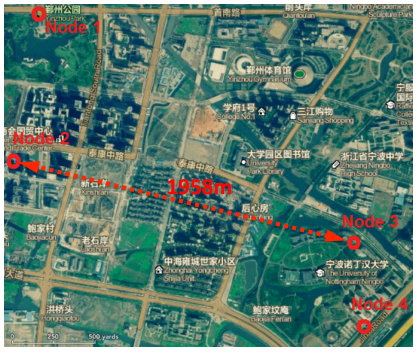
Alternative solutions under investigation:
Re-programmable RF system-on-chip (SoC)

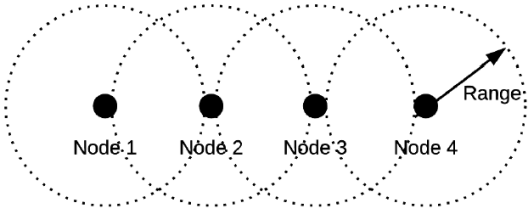
Range Testing

Image format: JPEG
Image size: 50 – 70 KB
Pixels: 320*640
Testing type: line of sight
Temperature: 17 degree
Air pollution index: 290
Transmission latency: 5 – 7 s

- The system will not fit in time-critical applications for the time being, however it will be effective for scenarios that are delay-tolerant in the order of seconds, e.g. traffic surveillance, environmental monitoring.
- The relatively long transmission range (compared to WiFi and Zigbee) also makes the system suitable for deployment in large dimensions, such as city scale.

Multi-Hop Image Sensing Network





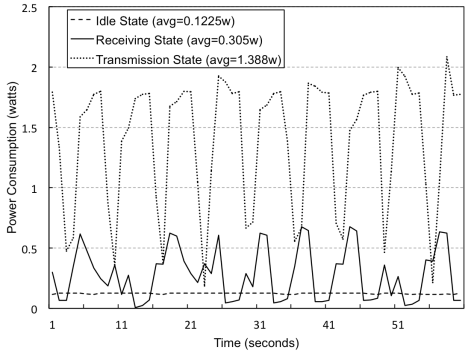
(a) Image Received from Node 1

(b) Image Received from Node 2

(c) Image Received from Node 3

Power Consumption

- Using a pair of AA alkaline batteries with a total energy of 7.8 wh, this system can operate continuously in the transmission state for approximately 5 hours, 25 hours in the receiving state, and 63 hours in the idle state.



Summary

- Traditional WSNs normally require specialized design and implementation.
- WMSN drastically stretches the horizon of the traditional monitoring and controlling system based on WSN, while being subject to current technical limitations.
- Pervasive WSN is a vision to bring sensing functionalities to our daily lives, which takes advantage of smartphone facilities. (This topic will be discussed in the next lecture.)

Questions?

- **Email:** x.che@herts.ac.uk
- **Office:** LB218
- **Tel:** 01707 286206