WIRELESS DISTRIBUTED NETWORK FOR CLOUD COMMUNICATIONS

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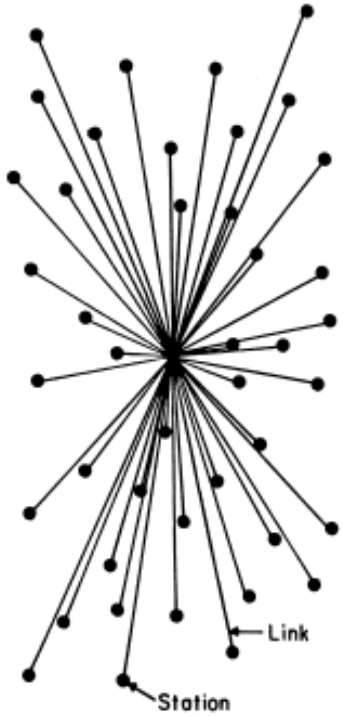
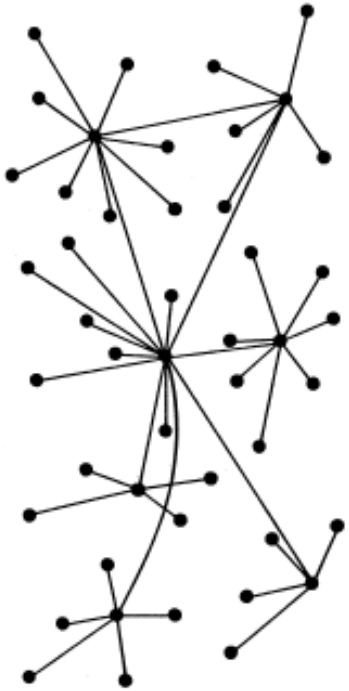
ATNAC 2013 & 22 ITC SSEEGN
20-22 November 2013, Christchurch, New Zealand

WiNG wireless innovations

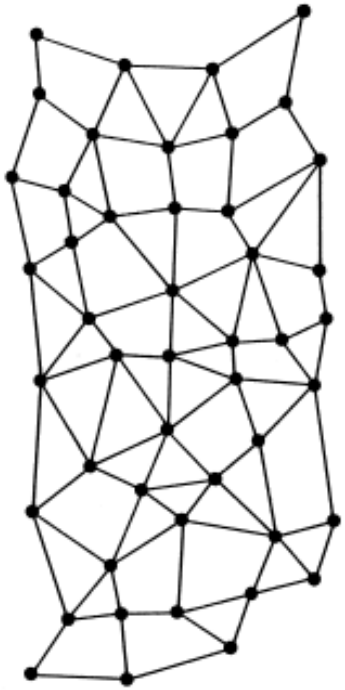
Centralized to Distributed



Centralized



Decentralized



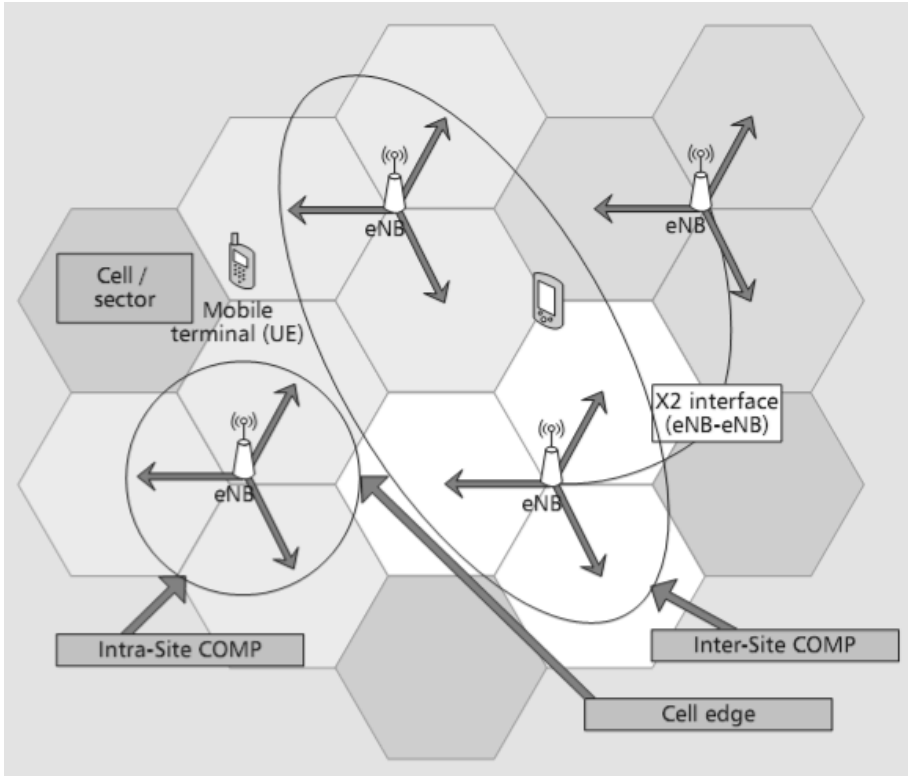
Distributed

CLIENT-SERVER PARADIGM

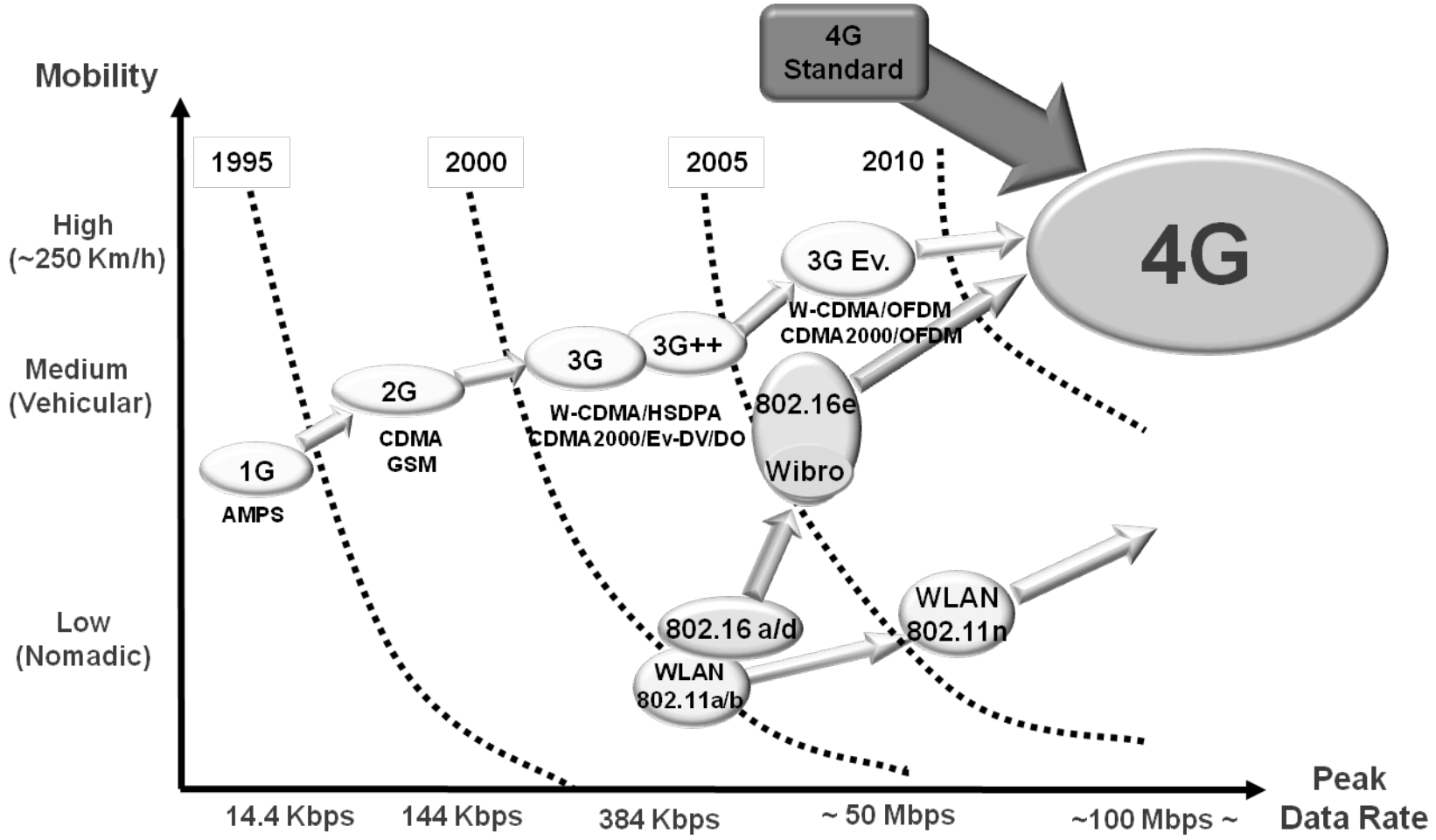
- Traditional client-server based networking paradigms extensively rely on complicated multi-layered hierarchical architectures
- Example: Wireless cellular networks
  - Gateway server nodes are centrally positioned at the network's core, where they need to be large enough to serve multiple base stations
  - All network traffic need to traverse to these servers located at the edge of the core network
    - Thus creating long distance traffic backhauling and network bottlenecks ➔ **Delay and Congestion**

Cellular Networks

- Highly centralized and controllable
- Quality assurance as per customer service guarantee (CSG) models
- Low network flexibility or openness

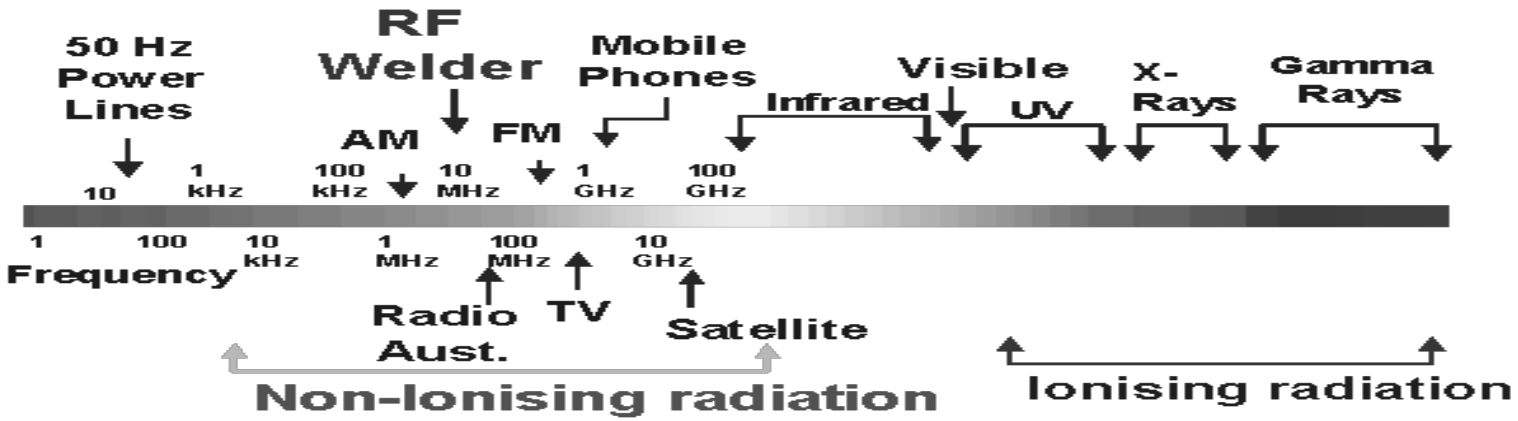


Higher Mobility and Data Rate



Wireless R&D Goals

- Efficient use of the scarce frequency spectrum
- Efficient use of the transmitting power
- Correct delivery of information between source/destination
- Avoidance of network congestion
- Assurance of service quality
- Fair resource sharing by optimized bandwidth use
- Delivery of new services as they arrive

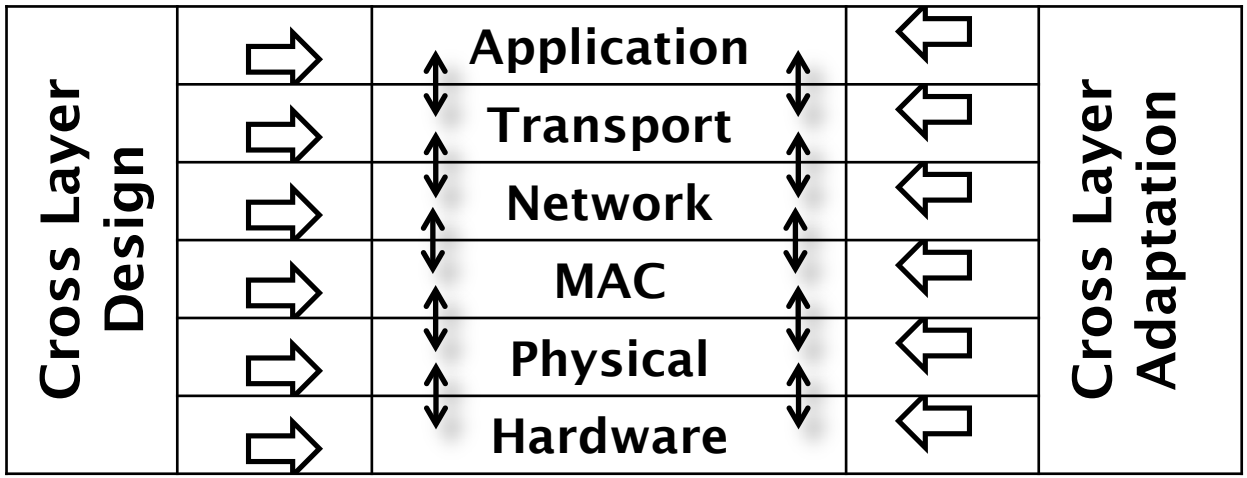


Wireless R&D Areas

- Three focus areas of R&D in wireless field
  - **Transmission:**
    - Physical layer (freq. and antenna design, encoding schemes, transmission media, modulation/ demodulation techniques)
    - Link layer (medium access control, multiple access, error detection and error correction)
  - **Networking:**
    - Network layer (routing techniques, congestion control, traffic control, mobility management)
    - Transport layer (TCP/UDP design, RTP)
  - **Services:**
    - Application layer (application design, security protocols, compression algorithms, socket programing)

Cross-Layer Optimization

- Cross-layer coordination and optimization among the network's protocol stack layers

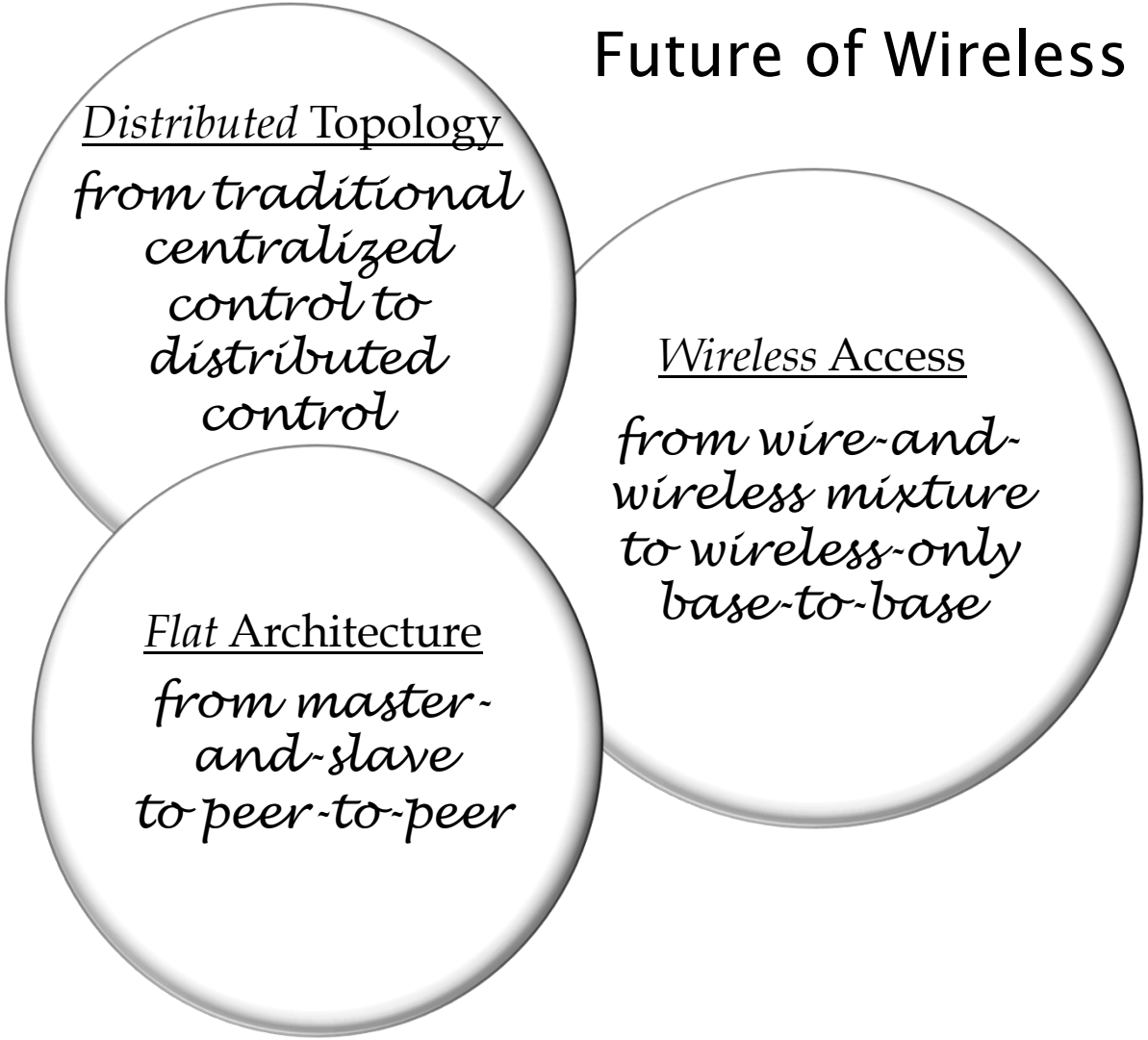


facilitating easier cooperation among multiple networks in a HetNet or distributed environment

Cooperative Networks

- New flexibility and enhanced capabilities as a result of advancement in radio technologies
- Moving from the traditional centralized systems to cooperative wireless mode
  - Possible operation of multiple independent nodes together to form a wireless distributed network
  - Exploiting the wireless connectivity to share processing-intensive tasks among multiple devices
  - Improving performance, operating efficiency, and system capabilities

COOPERATIVE → DISTRIBUTED



Future of Wireless Networks

towards networks which are

- ✓ *Autonomous*
- ✓ *Scalable*
- ✓ *Fault Tolerant*
- ✓ *Upgradeable*
- ✓ *Resource Unlimited*

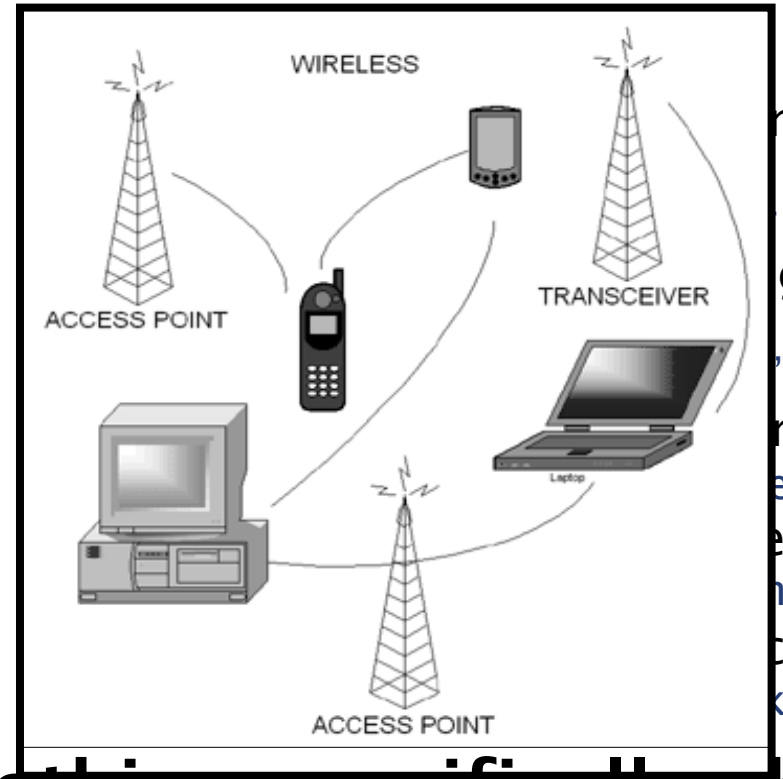
Distributed Wireless Networks

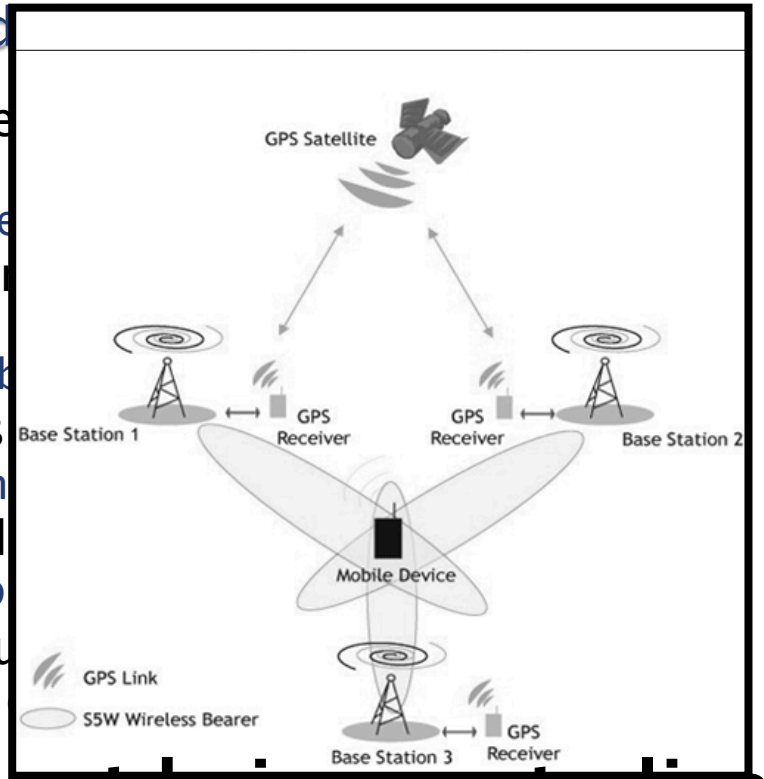
Objectives:

- Reduction in per-node and network resources
- Enabling complex applications not otherwise possible
  - Examples: Image processing in a network of many radio nodes; Geographical navigations
- Allowing dynamic radio operation
- Meet design and implementation challenges for future applications under limited spectrum availability and resources

WIRELESS – BASICS

- Definition
  - *Any collection of elements that deploy unguided electro-magnetic wave propagation to perform a specific function*





Nothing specifically about being centralized!

FLAT ARCHITECTURE

- If the network architecture conceptualizes a distributed design, it will be capable of
  - significantly reducing the complexity of the network
  - providing the foundation for a sustainable service delivery platform (i.e., optimized use of bandwidth and power)
- A distributed design could offer operators a range of improved business and performance benefits compared to the centralized approach
- Subscribers can enjoy an enhanced experience as the distributed approach
  - Brings the service edge close to the user
  - Eliminates single point-of-failure
  - Provides faster services

Flat Distributed Architecture

- Consists of three layers:
  - Distributed antennas
  - Distributed signal processing
  - Distributed high-layer control protocols
- Started to be seen in cellular too
  - 3GPP's long-term evolution – system architecture evolution (LTE-SAE) has a much flatter architecture compared to UMTS
  - Functionality of eNB and MME/S-GW is combined into a single entity

Existing Supports

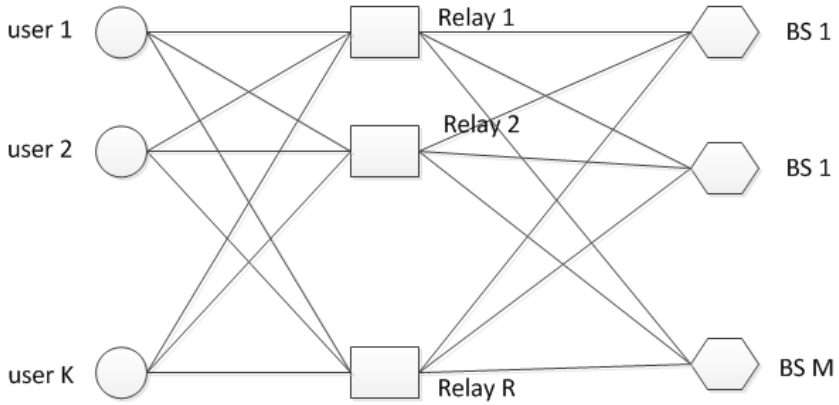
- Modern mobile devices have abundant unutilized processing power and information on peer nodes
- Self-organizing ad-hoc networks are now possible for effective nodes cooperation
- Mobile devices are not anymore simple objects for communications
  - They are capable of collecting and processing information and sharing them with other nodes

KEY TECHNOLOGIES

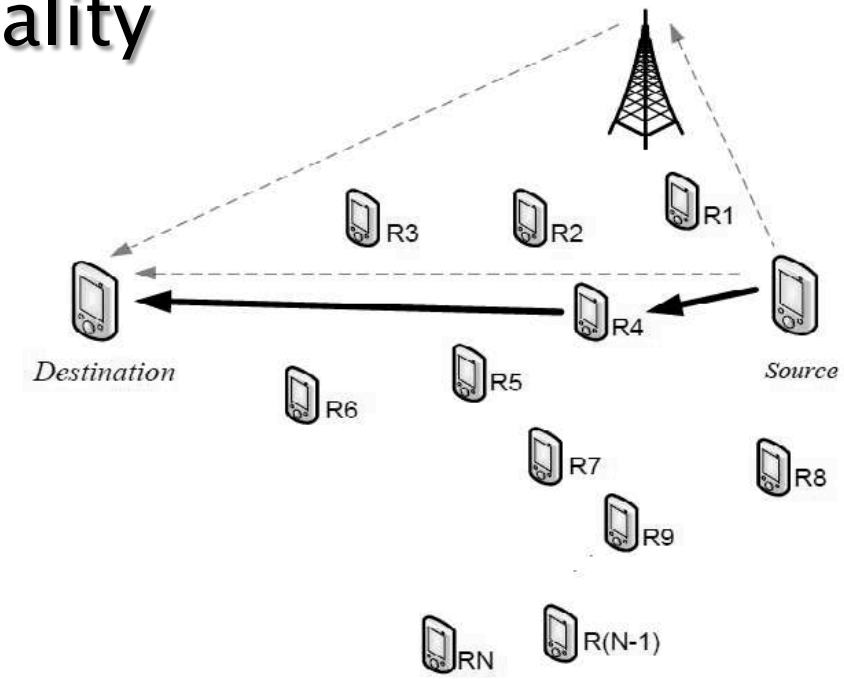
- Technologies needed for cooperative wireless computing, flexible link design, adaptation, and autonomous operation already exist
  - Fault tolerant computing algorithms
  - Distributed computing techniques
  - Software defined radio capabilities
  - Cognitive radio and spectrum management techniques
- To provide
  - Flexible and optimized resource management
  - Reliable wireless communication
  - Joint optimization of computation and communication processes
  - Customization of the QoS needs for users

Relay-Assisted Cellular Networks

- To reduce delay or transmission power
- To extend the coverage area
- To improve signal quality



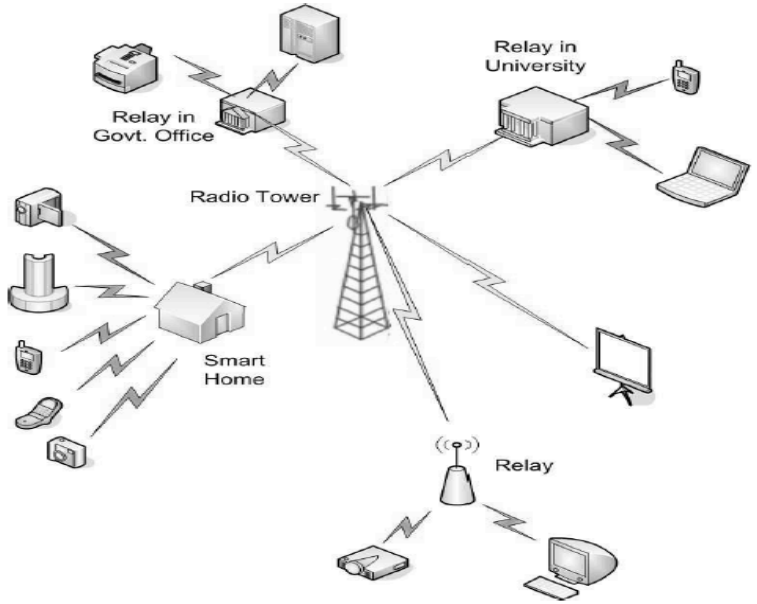
MIMO Relaying



Simple Relaying

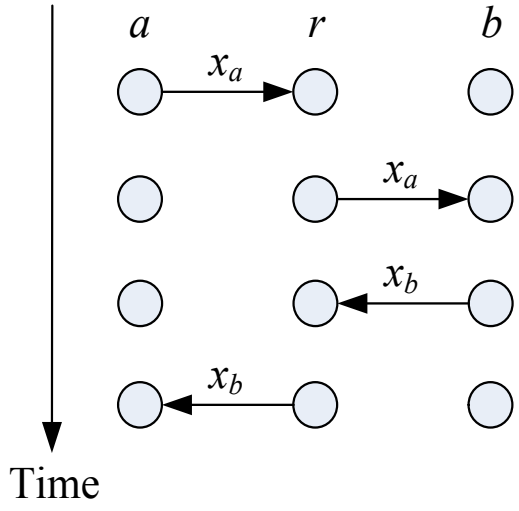
Multi-hop Relay Networks

- A technique for communication between a source and a destination via some relay nodes with limited transmission ranges
  - Transmission of the received signal by each relay after performing some processing of its own

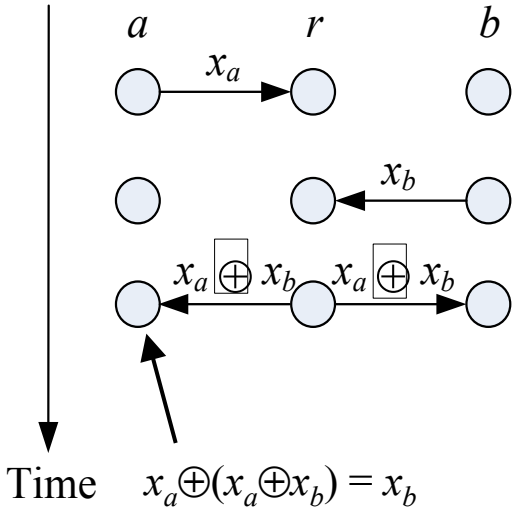


NETWORK CODING

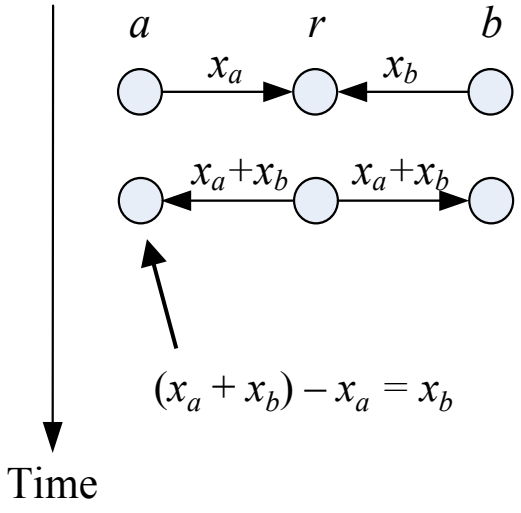
- Save transmission time
- Improve throughput



Conventional Relaying Scheme



Conventional Network Coding - CNC



Physical-Layer Network Coding - PNC

A promising technology to improve the throughput performance of relay networks by employing the natural network coding ability introduced by the superposition of electromagnetic waves

Network Coding Challenges

Network Layer

- Relay node selection
- Relaying method selection
- PNC-aware route selection

Link Layer

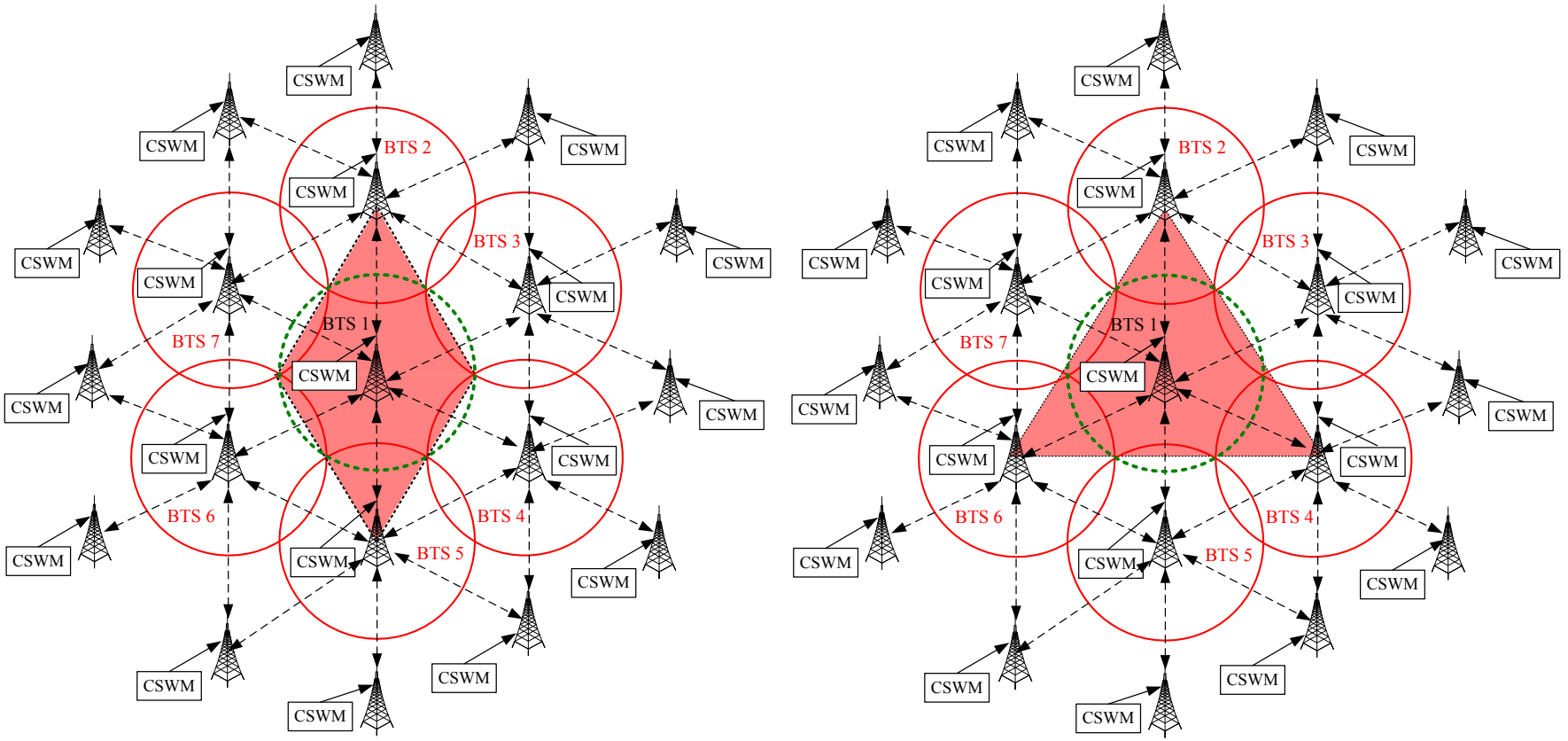
- PNC-aware link scheduling
- Simultaneous transmission coordination

Physical Layer

- Transmission power control
- Synchronization
- Integration of channel coding and PNC
- Modulation of superposed signals

Cooperative Communications

- Cooperation among BSs can provide load balancing and overall energy consumption

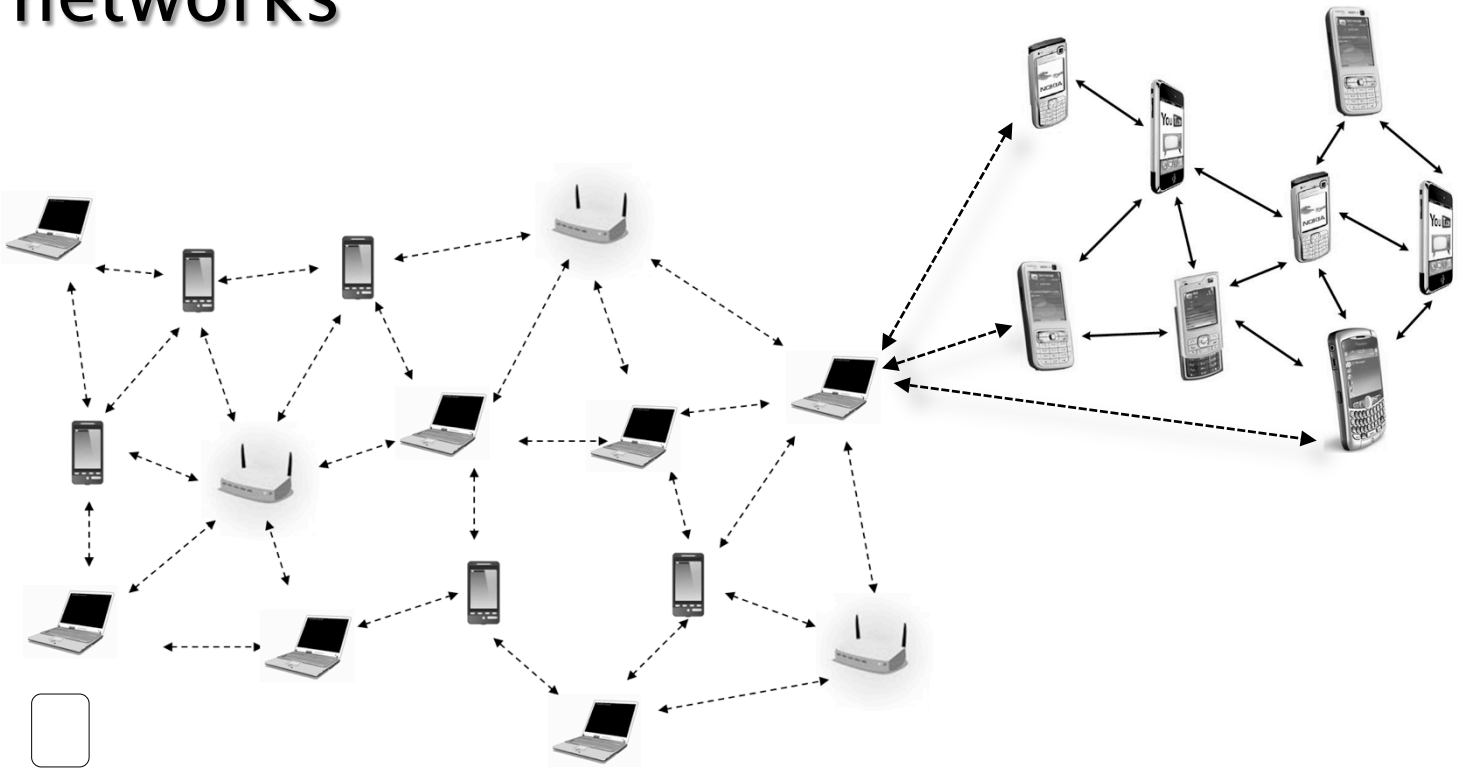


Available Network Topologies

- Cellular based systems (centralized)
  - In line with the current infrastructure and coverage
- Mobile Ad hoc networks (decentralized)
  - Distribution of responsibilities of network elements
  - To add coverage, capacity, and new services for example through vehicular communications (VANET)
- Wireless Mesh networks (hybrid centralized and decentralized)
  - Different from the existing cellular network star topology
  - Avoiding the main limitations of a wireless network for high transmission power and multipath transmission
    - Covering short range, so low power transmission
    - No ugly towers
    - Mostly LoS, so no multipath transmission problem

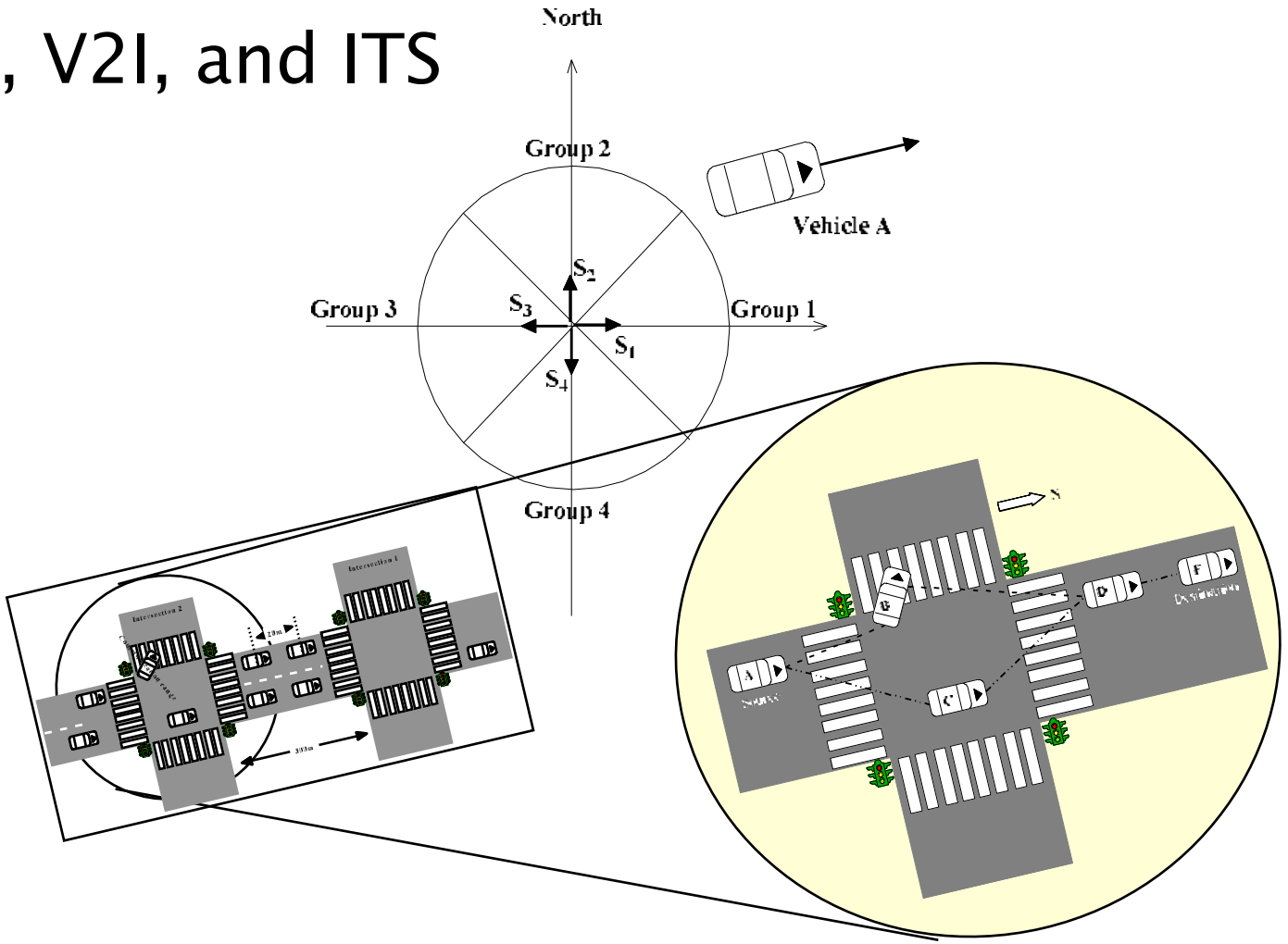
Mobile Ad Hoc Networks

- A relatively old topic but using the same concepts as for flat and distributed networks



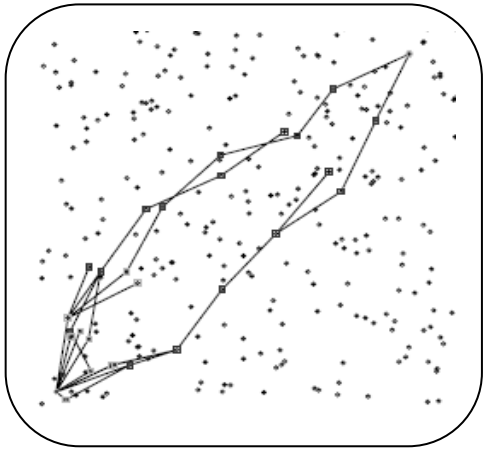
VEHICULAR AD HOC NETWORKS

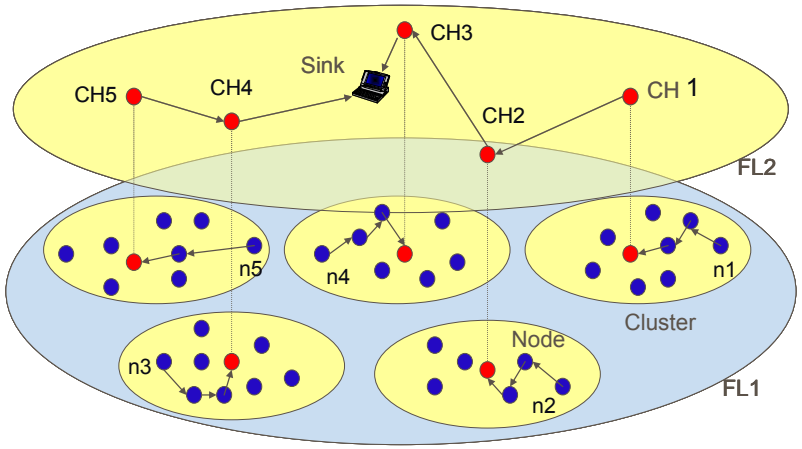
V2V, V2I, and ITS

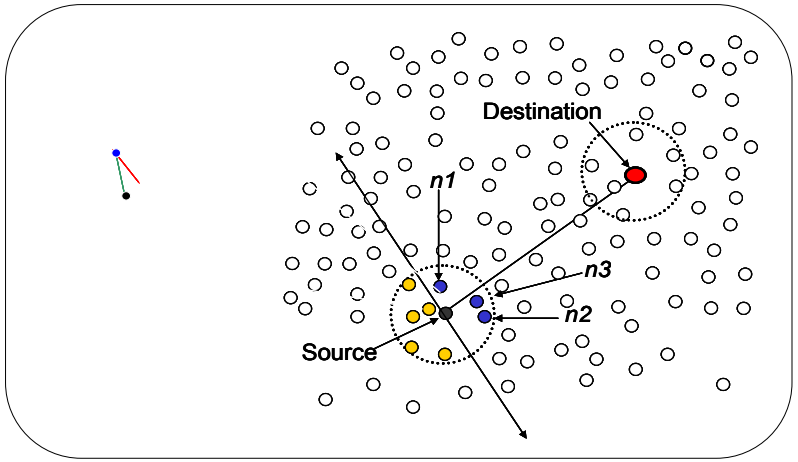


WIRELESS SENSOR NETWORKS

- Sensor clustering for efficient routing
- Layered topology design for better data aggregation





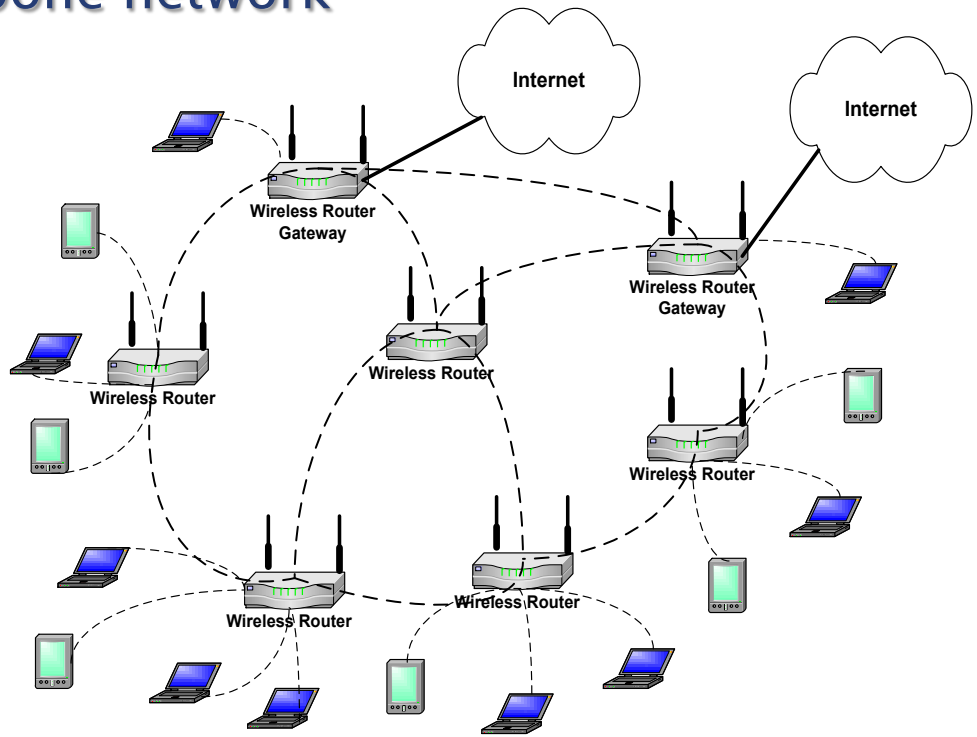


- Secure sensor networking

Wireless Mesh Networks

Mesh Networking

- Developing a new backbone network
- Advantages:
  - Emergency applications
  - Fault tolerance
  - Added throughput
  - Reliability

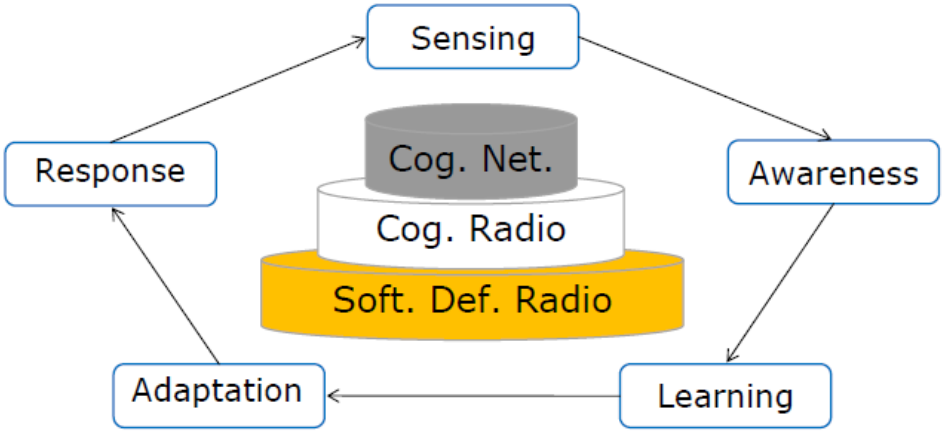


Cognitive Radio Networks

- Opportunistic radio spectrum access
  - Secondary usage of the spectrum holes
  - Co-existence with other systems
  - Spectrum aware, spectrum adaptable
- Smart and reconfigurable radio
  - For better spectral efficiency
  - For flexible radio functionalities
  - For interoperability among
  - For making network self organizing

Spectrum Holes

- Frequencies not in use by a "primary user"
  - "Holes" can be found in time, space, or power domains
- Sense those frequencies and "opportunistically" use them by a "secondary user"



Technologies

- ✓ Mobile Cloud
- ✓ M2M
- ✓ D2D
- ✓ IoT
- ✓ SDN

Mobile Cloud

- A combination of Wireless Radio and Cloud Computing technologies
- Collaborative use of resources among multiple network providers
- Take the advantage of the emerging cooperative MIMO technology with interconnection among the base stations
  - Decoupling BS from the radio head
  - Locating BS equipment at data centers
  - Using software radio for baseband processing
  - Supporting multiple standards in the same BS

Mobile Cloud

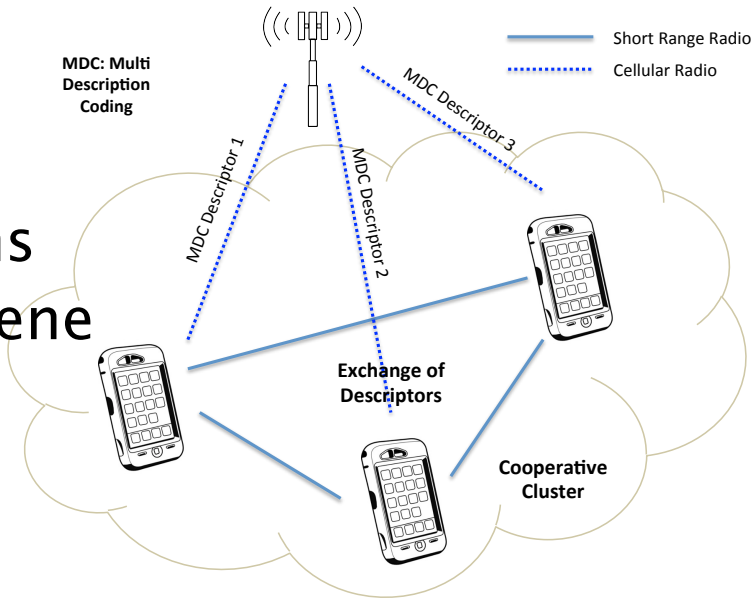
- To share abandoned mobile devices' resources over wireless cyber cloud
  - Time, space, and spectrum
  - Short-range and cellular radio
  - Processing power and memory
  - Visual, temporal, location sensors
  - Output devices (mic., speaker, display)
  - Files and program applications

HSDPA LTE LTE-A

Bluetooth Wi Fi

Mobile Cloud Applications

- Distributed video broadcasting
- GPS data on the cloud
- Camera sharing
  - Increase image resolution
  - Reduce hand-shake effects, blurring, poor light conditions
  - Produce 3D models of the scene
- Issues
  - Why to share resources
  - Security and privacy during sharing
  - Battery life of mobile devices

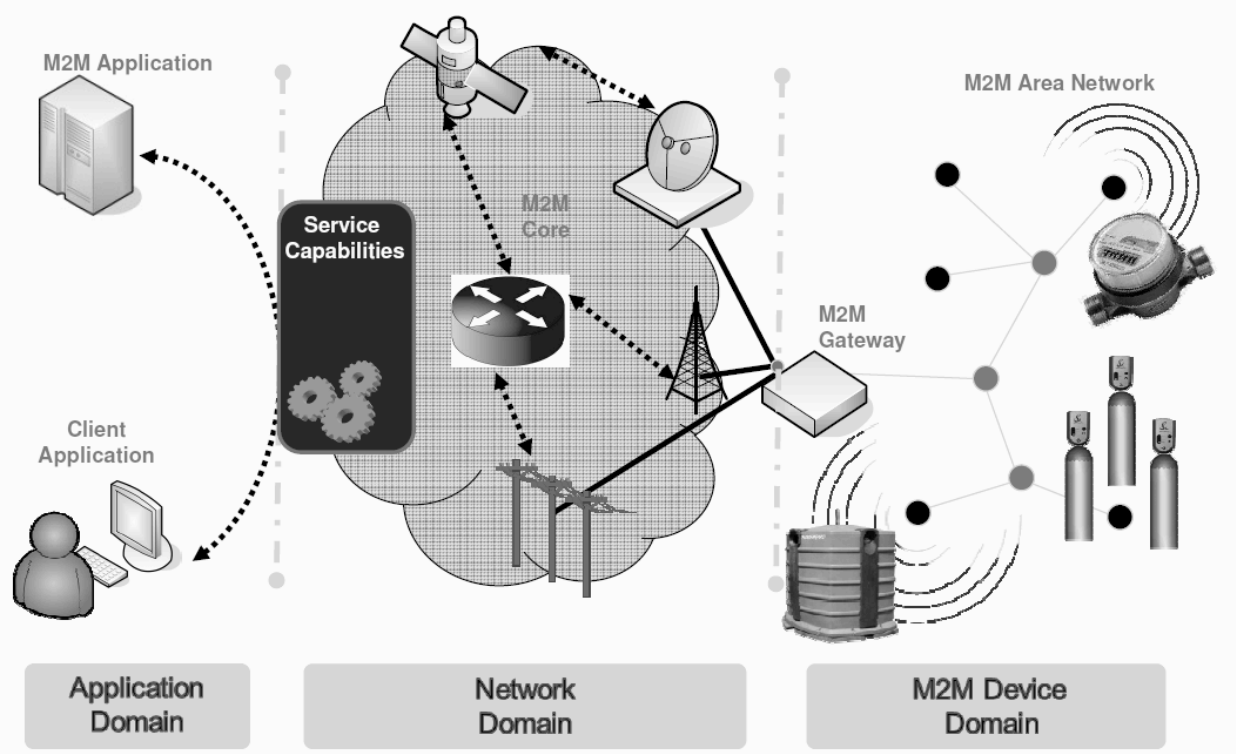


Machine-to-Machine: M2M

- A system characterized by:
  - support of a large number of nodes
  - seamless domain inter-operability
  - autonomous operation
  - self-organization
  - power efficiency
  - …
- Different Visions of M2M
  - WWRF [2007-10]: 7 Trillion devices by 2017
  - Market Study [2009]: 50 Billion devices by 2010
  - ABI Research [2010]: 225 Million cellular M2M by 2014

M2M Definition

- No human intervention whilst devices are communicating end-to-end

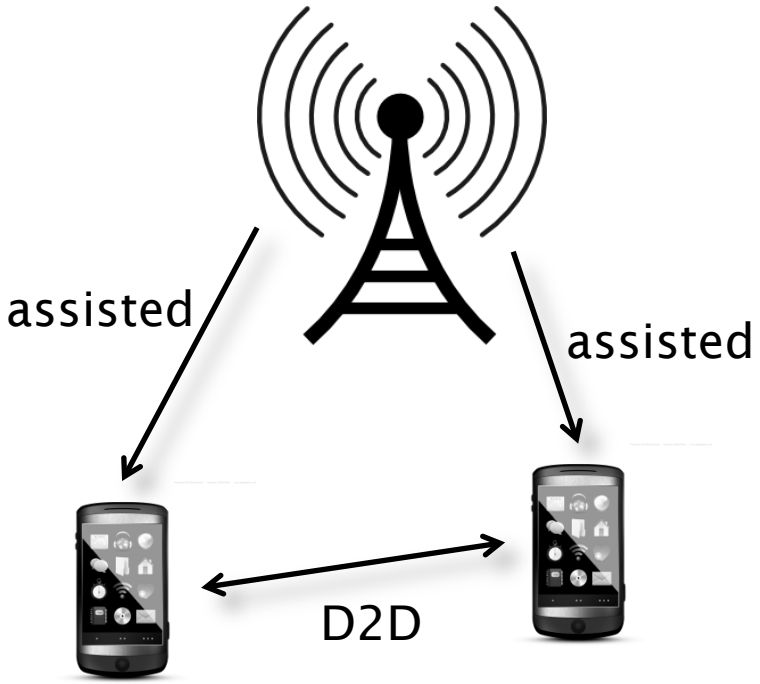


Source: ETSI

DEVICE-TO-DEVICE: D2D

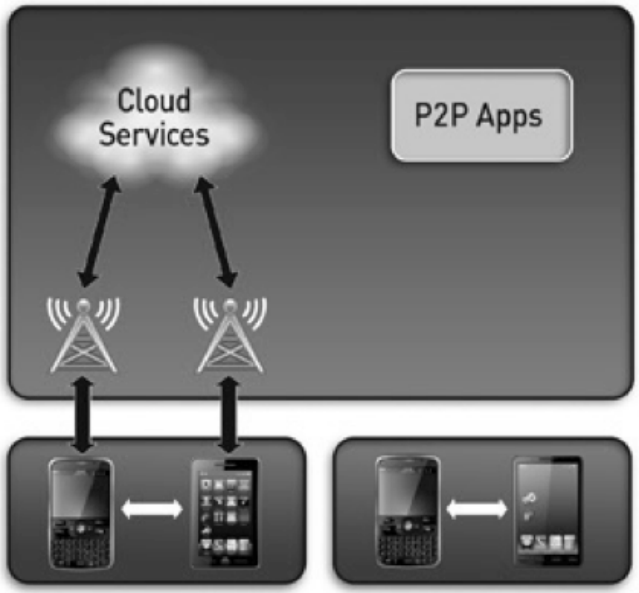
Enabling two or more mobile devices in proximity of each other to establish direct local links in either forms of:

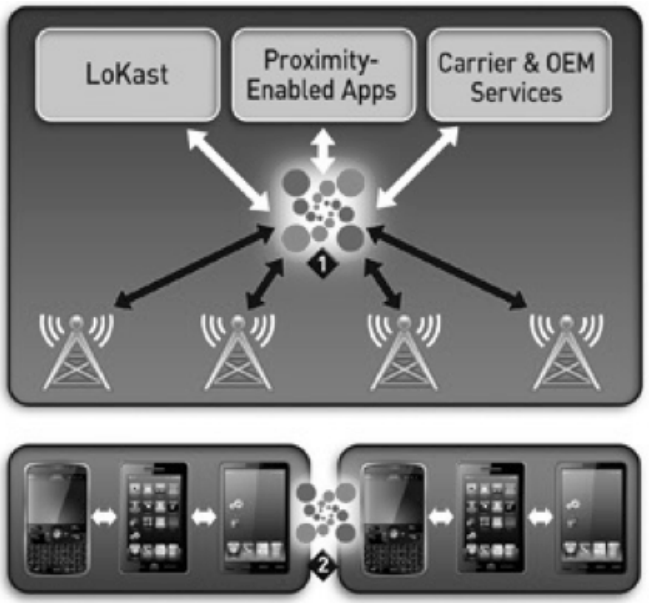
- In an autonomous manner to form an ad hoc network
- Coordinated by a base station to perform direct data transfer



D2D Communications Benefits

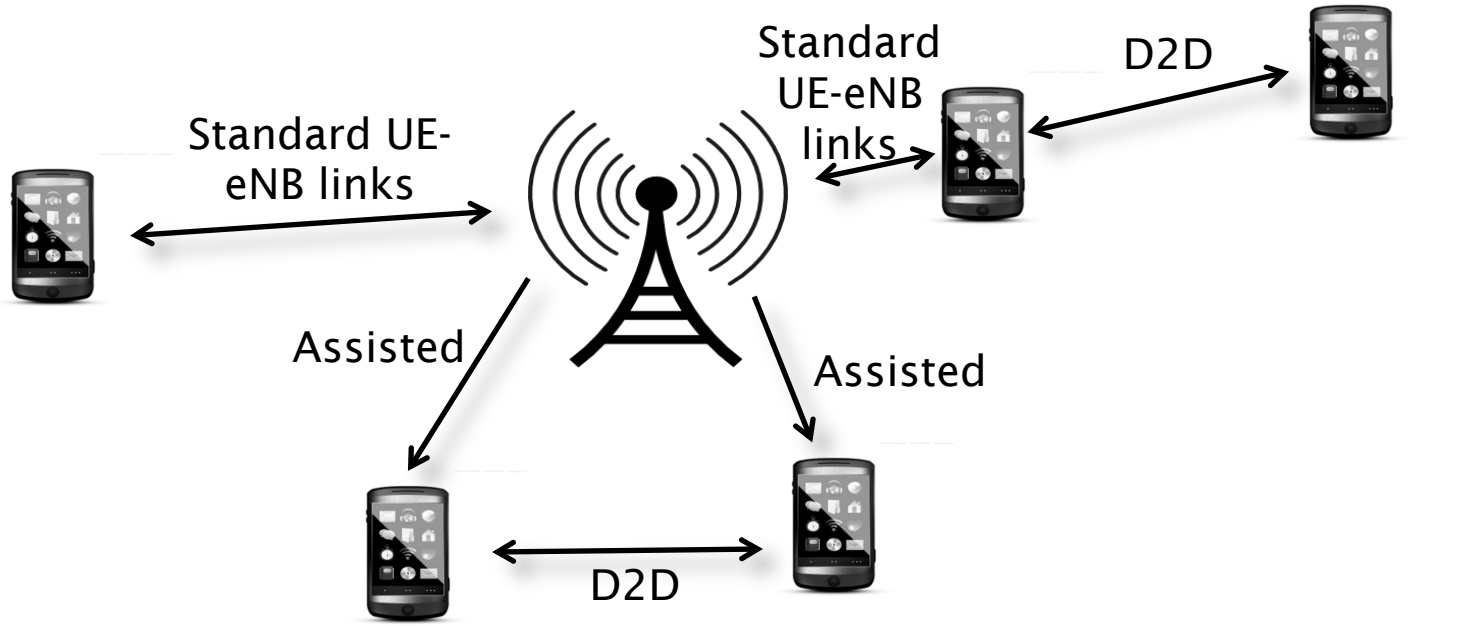
- Ubiquitous computing and communication, traffic offload from cellular networks, improved energy efficiency and coverage extension, peer-to-peer communication supporting social networks etc.





D2D Communications

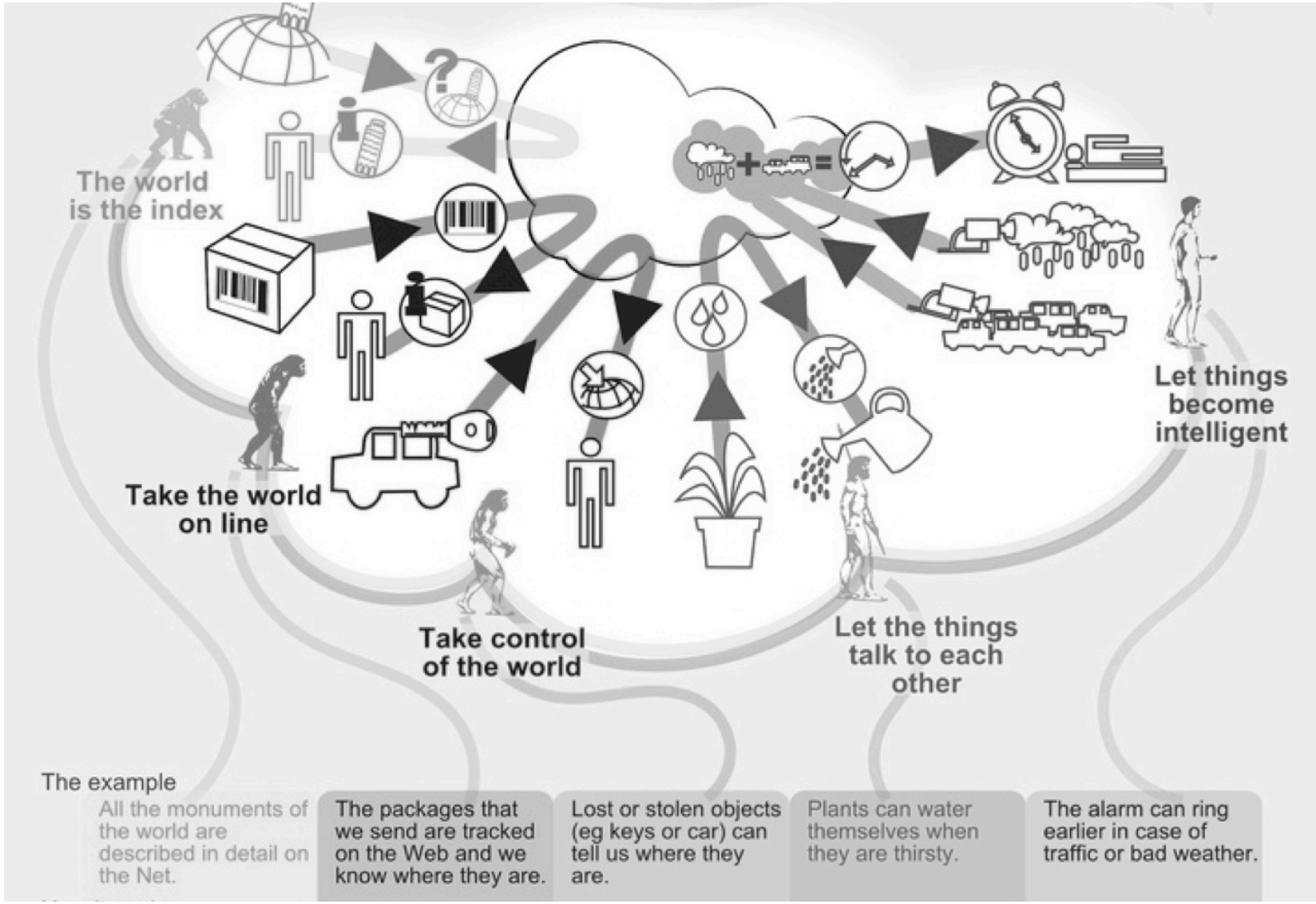
- Research areas
  - How to find device proximity?
  - How to manage interference?
  - How to control link quality?
  - How to achieve energy efficiency for neighbor discovery and multi-hop communication establishment?



Internet of Things: IoT

- A network of objects, such as household appliances
- Often a self-configuring wireless network
- First concept attributed to the original Auto-ID Center, founded in 1999 and based at MIT
- The idea is as simple as its application is difficult
- If all objects of daily life are equipped with radio tags, they can be identified and managed by computers in the same way humans can

An IoT Example



Software-Defined Cellular Networking

- Software-Defined Networking (SDN) has successful implementations in WANs and data center networks
- *The next step:* Adopting SDN in cellular networks in order to deal with
  - Ever-increasing capacity demands
  - Need for differentiated QoS/QoE
  - Accommodation of new services & applications
- SDCN could provide much needed flexibility, scalability, agility and efficiency for carriers

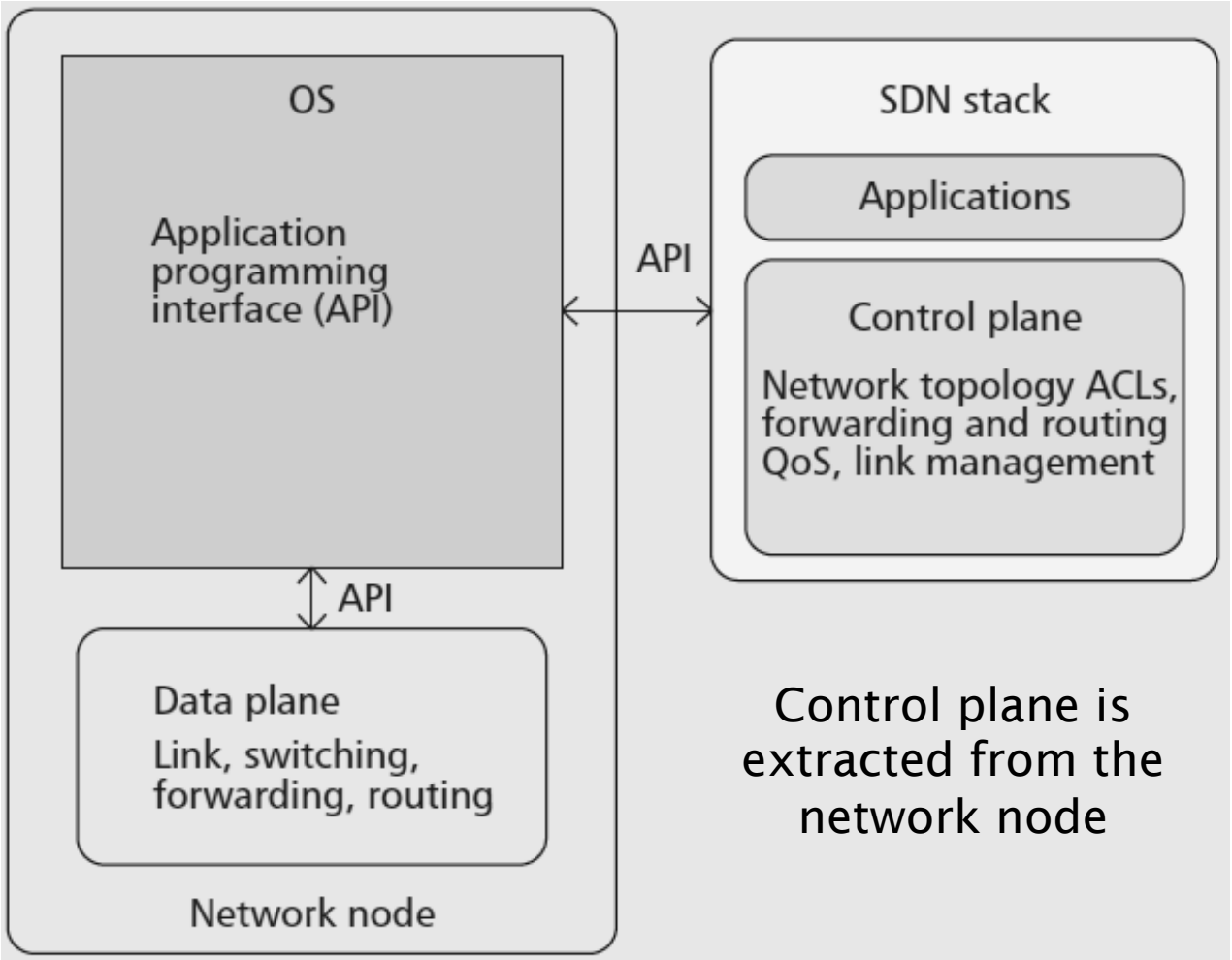
Current Cellular Problems

- Bandwidth Shortage
  - Powerful smart terminals require more BW than what even 4G provides. BW shortage extends also to backhaul and core networks.
- Need for more QoS Diversity
  - Current networks are not flexible, smart, or agile enough to offer QoS assurance
- Operation & Maintenance Complexity
  - Dedicated vendor-based hardware in current networks has inefficient and expensive O&M
- Revenue Loss
  - New applications make traditional revenue generating carrier services obsolete

One Solution: SDN

- Decoupling network control and forwarding data functions
- Implementing decoupled control plane in software in a logically centralized server
- Abstracting underlying infrastructure for applications and network services
- Application plane then is implemented above the control plane
- Result: S&A are now *untied* from details of network implementation!

TRADITIONAL NETWORK VS SDN



S. Sezer et al., "Are we ready for SDN? Implementation challenges for software-defined networks," IEEE Communications Magazine, pp. 36-43, July 2013.

SDCN by Carriers and Vendors

- SoftCOM (Huawei)
  - Applying SDN and cloud computing in carrier net.
- Service Provider SDN (Ericsson)
  - Extending virtualization and OpenFlow
- JunosVContrail (Juniper)
  - Delivering complete virtualization in carrier net.
- SDN/OpenFlow Controller & Switch (NEC)
  - Focusing on infra, O&M, service provisioning
- Other start-ups: Tellabs, Taif-f Systems, Accedian, Elephant Talk, …

SDCN Activities in Academia

- OpenRadio: targeting a programmable wireless network data plane that provides modular and declarative programming interfaces across the entire wireless stack
  - M. Bansal, et al., "OpenRadio: A Programmable Wireless Dataplane," HotSDN'12, Finland
- CellSDN: enables four main extensions to the existing SDN architecture, namely flexible policies on subscriber attributes, scalability through local switch agents, flexible switch patterns and actions, and network virtualization on subscriber attributes
  - L.E. Li, et al., "Toward Software-Defined Cellular Networks," EWSDN'12, Germany
- SoftRAN: focused on solving efficiency problems emerging in RAN based on SDN technologies
  - A. Gudipati, et al., "SoftRAN: Software Defined Radio Access Network," HotSDN'13, Hong Kong

CLOSING

- Benefiting from huge processing power and storage capacity of individual nodes, communications system will eventually move from the traditional centralized architecture into a distributed and flat platform
- SDN on the contrary is proposing to move some individual node functions into a cloud-based centralized network

- *So, what would be the compromised solution?*
  - Fully distributed control and data, *or*
  - Distributed clusters of centrally controlled nodes, *or*
  - SDN-type virtualized centrally control

Wireless Distributed Network for Cloud Communications

Thank You

AJ

21 November 2013

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