Wireless Networking

Driving forces & Research issues

- Wireless technology landscape
- Driving forces for technological advances
- New or existing spectrum allocation to be readily adopted
- Access to capital
- Internet
- Widespread demand for always-on access to data

Wireless Networking

State of the art

- **Cellular Systems** (UMTS, CDMA 2000)
  – Circuit based
  – Complex
  – Expensive
  – Narrow bandwidth (< 2Mb/s)
  + Mobility
  + Global access
  + QoS

Wireless Networking

State of the art

- **WLAN** (IEEE 802.11)
  + SSpectrum   CSMA/CA
  + Packet based
  + wide band access
  – No QoS
  – no mobility (hand over)
  – stand alone system

Wireless Networking

Next goals

- **Greater data rates**
  – Spectral efficiencies an order of magnitude greater than today
- **QoS for multimedia applications**
  – Design methodologies that blurs the lines between (OSI) layers and attempt to optimize across layer functionality
- **WLAN and AD HOC as access extension**

Spectral Efficiency

Layer 1

Three promising technologies:

- Ultra Wideband Communications
- Orthogonal Frequency Division Multiplexing
- Space-Time Architectures

Ultra Wideband Communications UWB

- Approved by FCC for communications and sensing applications
- Ultra short baseband pulses with a bandwidth of several GHz
- No radio frequency up conversion: a base band transmission that propagates at RF frequencies
- Can simultaneously coexist with existing RF devices throughout the spectrum
- Extremely low power spectral density
- Reliable data rates exceeding 100Mb/s within buildings
- Extremely low-cost wideband transmitter devices

Orthogonal Frequency Division Multiplexing OFDM

Based on an Old concept today attractive due to recent advances in high-speed and powerful VLSI

Unique features:

- Robust against multipath fading and inter-symbol interference
- Adaptive modulation and power allocation across sub-carriers
- Robust against narrowband interference
- Single frequency networks
- Adopted in IEEE 802.11
- Candidate for fourth-generation broadband multimedia wireless communication systems

Open issues

- Large peak-to- average power ratio which reduces power efficiency in RF amplifier
- Susceptible to frequency offset and phase noise

Space-Time Architectures

- Space-time processing technology and multiple-input-multiple-output (MIMO) antenna architectures exploiting small-scale temporal and spatial diversity with antennas and error-control codes vastly improves spectrum efficiency
- May be used in both cellular and ad-hoc network architectures
- Smart antennas effective
  - in range improvement (cellular systems)
  - in throughput increase due to suppression of co-channel interference (CELL SYS & WLAN)
- Diversity obtained by temporal, frequency, spatial and polarization spacings mitigates deep fadings
- Small complexity to increase spectrum efficiency
- Significant gains in
  - Energy efficiency
  - Spectral efficiency

Hybrid approach
Physical-MAC layers integration

- Improves spectral efficiency with Hybrid FEC-ARQ on interference limited channels and/or fading channels
- Delay can be traded against spectral efficiency
- QOS adaptation

New Network Design methodologies (1/3)

Past/Present

Layered OSI design methodology

- Physical Layer: modulation, power control, data rate, spreading
- Data Layer Link: frame size, FEC, ARQ, power control, radio resources control, multiple access
- Network Layer: routing, congestion control, packet size, QoS

Emerging wireless networks must support:

- Various and changing traffic types with their associated QoS
  - Multi media traffic with manifold delay, error-rate and bandwidth requirements
- Changing topologies
  - Continuously entering and leaving nodes
  - Radio link failures
  - Lack of network infrastructure (ad hoc nets)

New Network Design methodologies (2/3)

Present/Future

- To meet the challenges of wireless networks the network functions must be considered together when designing the network
- Applications varying QoS requirements will force network layer to account for physical layer design to optimize network throughput
  - A scheduler based on feedback from mobiles
- Different applications are better served by different optimizations
  - Very strict delay requirements (voice) versus delay-insensitive (Web traffic)
- Cross-layer network design is a step forward the new multimedia network optimization

New Network Design methodologies (3/3)

A full optimization requires:

- **Cross-layer design**
  - Requires **static** optimization across network layers
- **Cross-layer adaptability**
  - Should allow all network functions to pass information between functions and adapt simultaneously
  - Needed to meet changing QoS requirements, networks loads and channel conditions
  - Requires **dynamic** optimization across network layers

Cross-Layer Optimization

- **Challenges and research issues**
- **Full network design and optimization is nearly intractable**
  - Real-time dynamic optimization
  - Find design methodologies that encompass the incredible freedom offered to the designer
- **Metrics to be used in the optimization**
  - Layer optimization had its own criteria:
    - Physical layer design focuses on bit-error rate minimization
    - MAC layer design focuses on node throughput and channel availability
    - Network layer design focuses on delay and routing efficiency

What metrics capture at best all concerns together?

Cross-Layer Optimization

- **Dynamic optimization**
  - Information is passed between networks layers
  - Appropriate information to be passed:
    - Not too complicated to avoid
      - Large delays
      - Computationally expensive optimization routines
    - Not too simplistic
      - To be effectively used

Very sophisticated modeling and simulation procedures are needed

Cross-Layer Optimization

- **Network simulators should be improved**
  - Not sufficient granularity to allow physical layer design
  - Adding network functionalities would result in too log run time
  - Network layer simulators are event-driven
  - Physical layer simulators are time-driven
- **Two-tier simulation approach**
  - The output of physical layer simulator is used in network layer simulator
  - No interaction between layers, poor cross-layer optimization
- **Hybrid approach**
  - Combined simulation of high-level functionalities with semi-analytic approach for lower-level
  - Combined simulation and hardware to perform lower-level functionalities
  - Variable-granularity: coarse granularity (abstracting lower layers) for most links and fine granularity for some of specific interest

Network Control

A control on the process of adaptation across layers is needed to coordinate on the same goal

Issues:

- Who has control
- Where locate the control for each layer
- Solution may depend on:
- end-user application
- physical operation environment

WLAN and AD HOC as access extension

- Different 802.11 WLANs coexistence is inefficient
- Frequency reuse must be increased
- AD HOC operation can extend access range
- QOS must be provided for multimedia traffic
- Roaming and hand-over must be provided

Further Key Research Themes

- Cheaper more ubiquitous radios
- Improved performance
  - IEEE 802.11 11 → 54 → 200+
    - Adaptive modulation schemes
    - Smart antennas
    - Adaptive MAC
- New radio approaches
  - UWB
  - OFDM
  - Space-Time Processing
  - Ad-Hoc Networks

Further Key Research Themes

- Flexibility
  - Multiple standards
  - Multiple services
  - New regulatory approaches

- Competition / Integration of various radio systems
  - LAN/WAN roaming
  - Vertical Handover
  - Multi standard embedded systems (BT, 802.11, GPRS)
  - VoIP over 802.11 (cell system competitor)