Challenges

- Wireless channels are a difficult and capacity-limited broadcast communications medium
- Traffic patterns, user locations, and network conditions are constantly changing
- Applications are heterogeneous with hard constraints that must be met by the network
- Energy and delay constraints change fundamental design principles

Cross-layer Design: A New Paradigm

- Application
- Network
- Access
- Link
- Hardware

Diversity
Adaptability
Scheduling
End-to-End Metrics

Substantial gains in throughput, efficiency, and QoS can be achieved with cross-layer adaptation

What leads to CLD?

- Advanced applications like VOIP, Web browsing, multimedia conferences & video streaming demanded
  - Widely varying and diverse QoS guarantees
  - Adaptability to dynamically varying networks & traffic
  - Modest Buffer requirements
  - High and effective Capacity utilization
  - Low processing overhead per packet
  - Video streaming high bandwidth requirements are coupled with tight delay constraints

Cross Layer Design

- CLD is a way of achieving information sharing between all the layers in order to obtain highest possible adaptability of any network.
- This is required to meet the challenging data rates, higher performance gains and Quality of Services requirements for various real time and non real time applications.
- CLD is a co-operation between multiple layers to combine the resources and create a network that is highly adaptive.

Cross Layer Design - Benefits

- Allows upper layers to better adapt their strategies to varying link and network conditions.
- Helps to improve the end-to-end performance given networks resources.
- Each layer is characterized by some key parameters, that are passed to the adjacent layers to help them determine the best operation modes that best suit the current channel, network and application conditions.
Cross Layer Signaling

- Method I – Packet headers
- Method II – ICMP Messages
- Method III – Local Profiles
- Method IV – Networks Services

Method I – Packet headers

- Interlayer signaling pipe stores the cross layer information of the Headers of the IPv6 packets
- It makes use of IP data packets as in-band message carriers
- There is no need to use a dedicated message protocol

Method II – ICMP Messages

- A message can be generated at any layer and propagated to any upper layer, thus a message is transferred using these holes rather than a pipe as in method I
- The messages are propagated through the layers using the "Internet Control Message Protocol (ICMP)"
- More flexible and efficient method
- Has to pass by network layer
- Only upward ICMP messages are reported

Method III – Local Profiles

- Cross layer information is abstracted from related layer and stored in separate profiles within a Mobile Host (MH).
- Interested layers can select profiles to fetch desired information.
- This is not suitable for time-stringent tasks like real time applications

Method IV – Networks Services

Channel and link information from physical layer and link layer are gathered, abstracted and managed by WCI – Wireless channel Information Servers.

Ex. 1 – TCP Performance

- Possible factors that affect the TCP performance of MANETs
- What’s the problem:
  - 802.11 MAC is invisible to TCP/UDP
  - Presents itself as a reliable but time-varying channel
  - Time-varying behaviour can be mistaken as ‘congestion’, leading towards reduced throughput
- Any solutions?
Ex. 2: Multi-User Scheduling

- Scenario: base station schedules downlink traffic to multiple mobile users; channels are not stable and have equal chances to be on/off

Naïve Scheduling

- Round-robin
- Each user gets 1/3 of the slots
- On an average, each user gets a data rate of 1/6 packet/slots

Smart Scheduling

- Suppose base station has knowledge about the channel status
- Try a simple policy: only send randomly among the ‘on’ channels
- What is the data rate for each user?
  - Chance of no sending: \((1/2)^3 = 1/8\)
  - Total data rate: \(1-(1/8) = 7/8\) packet/slots
  - Data rate for each user is therefore \(7/24\) packet/slots

Ex. 3 – Rate Adaptive MAC

- UDP throughput varies over distance by for different modulation schemes.
- Can we make 802.11 MAC adapt to channel quality?

802.11-based Rate Adaptive MAC

- Idea: send data at higher rates when the channel quality is good.
- The transmission rate can be set as required depending on the Modulation scheme
- The RTS/CTS are always transmitted at Base rate
- At receiver, it measures the signal strength and figures out the maximum rate at which the Data can be received given that signal strength
- This rate is then communicated through CTS
- Then the transmitter send the subsequent DATA packets at this data rate.
UDP Throughput vs Distance

Throughput: Adaptive Rate MAC vs Plain IEEE 802.11

Ex. 4 – Real Time Video Streaming
• Link Layer: Adaptive techniques are used to maximize the link rates under varying channel conditions.
  — MAC Layer: Assigns time slots, codes or frequency bands to each links.
• Network Layer: Network layer operates jointly with MAC layer to determine the set of network routes that minimizes congestion.
• Transport Layer: Scheduling is congestion-distortion optimized: selects the most important packet in terms of video distortion and transmits it in an order that minimizes congestion; avoids transmitting packets in large bursts.
• Application Layer: determines the most efficient encoding rate that will suit the given requirements for that application.

PSNR performance for video streaming

QoS Mapping Technique
• The QoS mapping and the Adaptation Module are the key factors of the cross layer design.
• It has to be designed to optimally match application layer QoS and the link (Transmission layer) QoS.
• The video application layer QoS and link-layer QoS are allowed to interact with each other and adapt along with the wireless channel condition.

References
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