Cross-Layer Mixed Bias Scheduling for Wireless Mesh Networks

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Outline

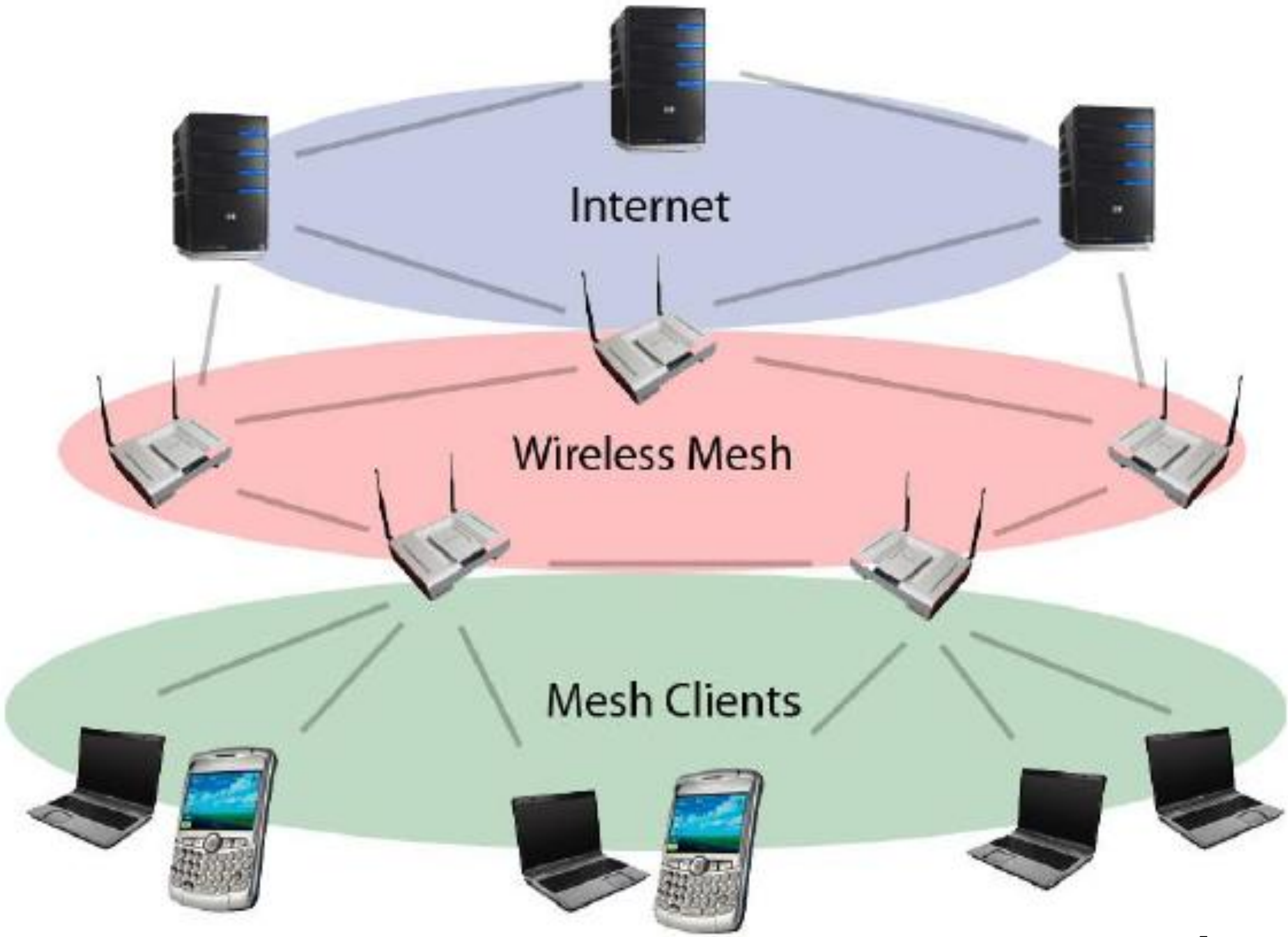
- Introduction
- Background & related work
- Proposed cross-layer technique
- Simulation environment
- Results & discussion
- Conclusions & future work

Introduction

- Consider Wireless Mesh Network (WMN)
  - Mesh Routers (MR)
  - Mesh Clients (MC)
  - Multiple Gateways (GW)

- Most traffic to and from Internet via GW

Introduction



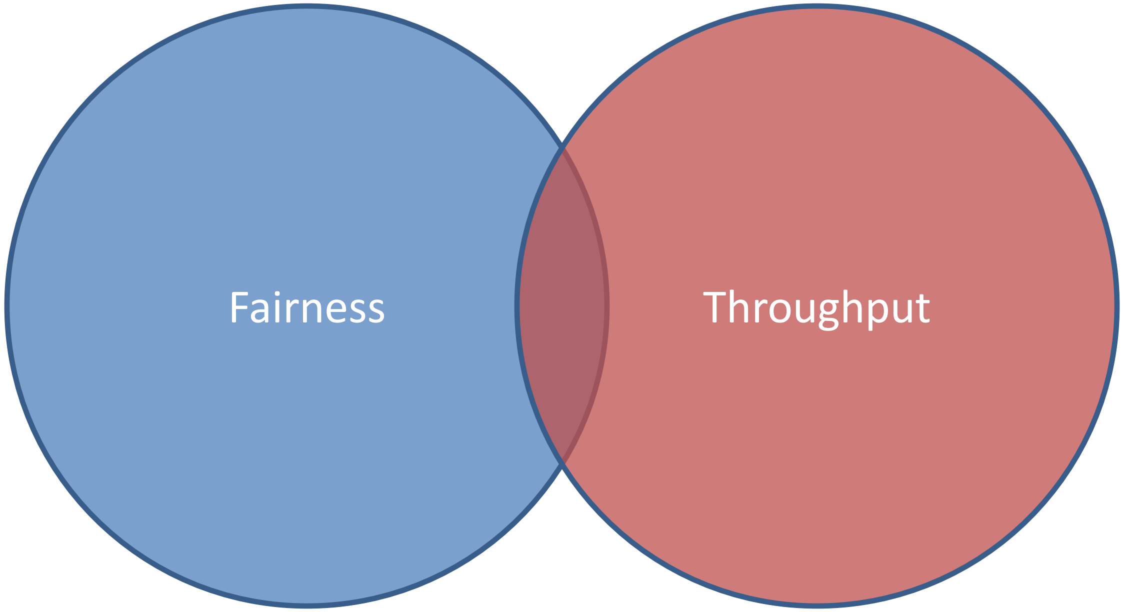
[Ernst, Denko, 2010]

Why Wireless Mesh Networks?

- Many Applications

  - Commercial & rural internet access
    - Cheap and easy to deploy compared with wired
  - Military communication, Search & Rescue
    - Few infrastructure required
  - Heterogeneous networks with WMN backbone
    - Autonomous: self-configuration, self-optimization, self-healing network

Why Scheduling?



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Background & Related Work

- Existing scheduling approaches:
  - Completely Fair (TDMA, FDMA etc)

$$R = \frac{1}{n}$$

- Where n is number of nodes

  - Wasted resources when a node has nothing to transmit

Background & Related Work

- Existing scheduling approaches:
  - Proportional Fairness
    - i.e. proportional bias against undesirable nodes
      - (often based on distance)

$$R = \frac{1}{c^{\beta}}$$

  - Good performance, but can be improved if we introduce multiple levels of bias (see mixed-bias)

Background & Related Work

- Existing scheduling approaches:
  - Max-min
    - Maximize the minimum flow
  - Mixed-Bias (Singh et al)
    - Allows multiple biases to be applied (strong + weak)

$$R = \frac{\alpha}{d^{\beta_1}} + \frac{1-\alpha}{d^{\beta_2}}$$

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Cross-Layer Mixed Bias Scheduling

- Based on work by S. Singh et al “Beyond Proportional Fairness...”

- Main contributions:
  1. Extended to apply to characteristics other than just distance
  2. Combined mixed-bias technique

Cross-Layer Mixed Bias Scheduling

- Layers used in the approach:
  - MAC Layer
    - Queue of packets ready to be transmitted into the medium
  - Network Layer
    - TTL / Number of Hops examined and reported to MAC
  - Physical Layer
    - SINR measure reported to MAC

Cross-Layer Mixed Bias Scheduling

- Our mixed bias technique:

$$R = \frac{\alpha}{c^{\beta_1}} + \frac{1-\alpha}{c^{\beta_2}}$$

  - Additional characteristics
    - Distance between GW and MR
    - Queue Size
    - Link Quality

  - Combined Technique
    - Biases against multiple characteristics at once

Combined Mixed Bias Scheduling

- Bias against multiple characteristics at once:

$$R = \gamma_1 R_1 + \gamma_2 R_2 + \gamma_3 R_3$$

- Where:

$$R_1 = \frac{\alpha_1}{c^{\beta_{11}}} + \frac{1-\alpha_1}{c^{\beta_{12}}}$$

$$R_2 = \frac{\alpha_2}{c^{\beta_{21}}} + \frac{1-\alpha_2}{c^{\beta_{22}}}$$

...

$$R_n = \frac{\alpha_n}{c^{\beta_{n1}}} + \frac{1-\alpha_n}{c^{\beta_{n2}}}$$

Combined Mixed Bias Scheduling

- 802.11 MAC Solution:
  - At each MR modify MAC queue:
    - Change ordering depending on bias
    - Allow a given packet to be bumped a fixed number of times -> avoid starvation
- TDMA Solution:
  - Assign time based on the bias, the stronger the bias, the less time a given node is given

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Simulation Environment

- NS3 simulation environment
  - OLSR Routing
  - Modified 802.11 MAC layer

- Metrics:
  - PDR, end-to-end delay

Simulation Environment

- Parameters:

Parameter	Value
Mesh Routers	10 – 30
Mesh Clients	250
Gateways	1 – 5
α	0.5
β_1	2
β_2	5
Environment Dimensions	1000 x 1000m
Node Range	150m

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Results & Discussion

- Evaluation against two different schemes
  - 802.11 Modified MAC
  - TDMA Based on previous work

Results & Discussion

- Combined M-B generally lower delay compared with 802.11
- Performance improvement with larger sized networks
- Improvement against M-B distance approach

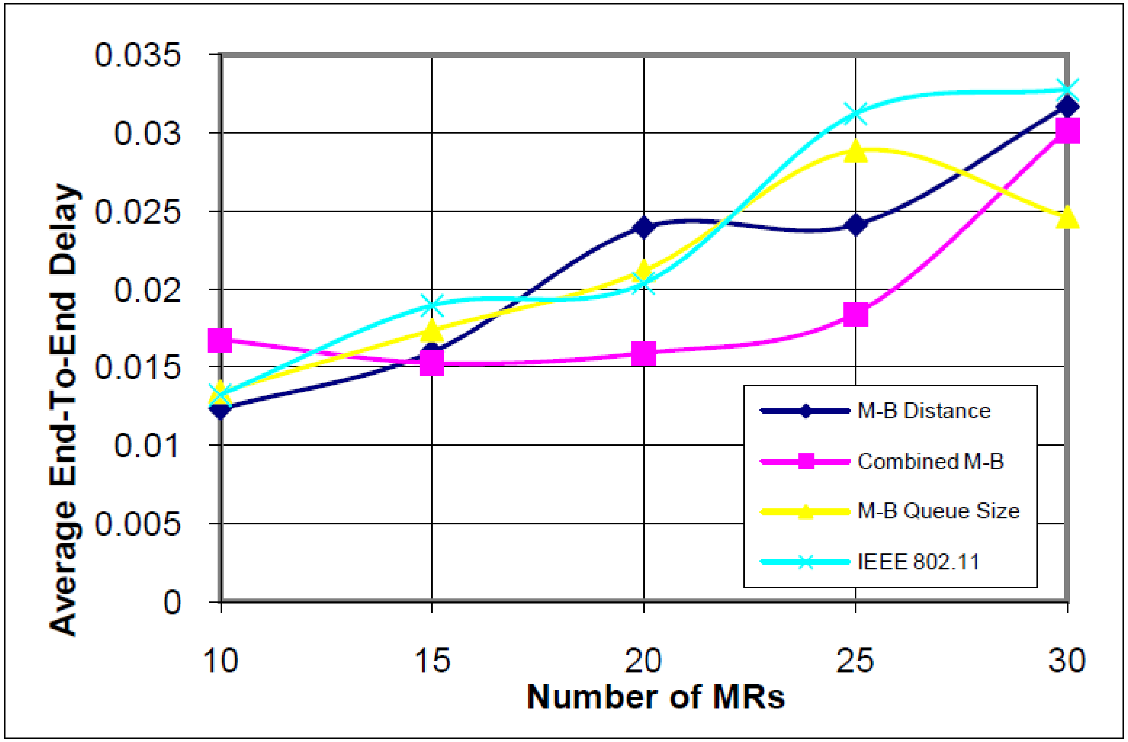

Figure 1 Average End-To-End Delay, Two Flows

Results & Discussion

- As network becomes more congested (more flows) the combined approach performs well

- M-B distance alone does not work as well in congested networks, since farther nodes have low priority

- M-B combined takes into account growing queues at far nodes

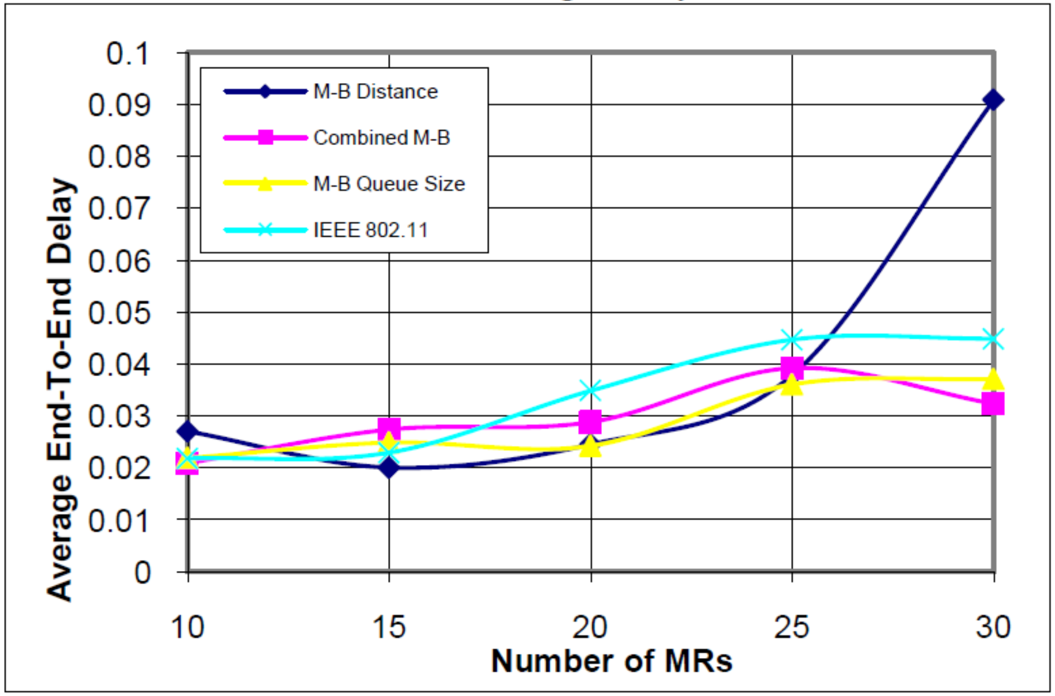

Figure 2 Average End-To-End Delay, Five Flows

Results & Discussion

- Shows that M-B approach is scalable with increasing number of gateways

- Improvement on original multiple gateway TDMA approach

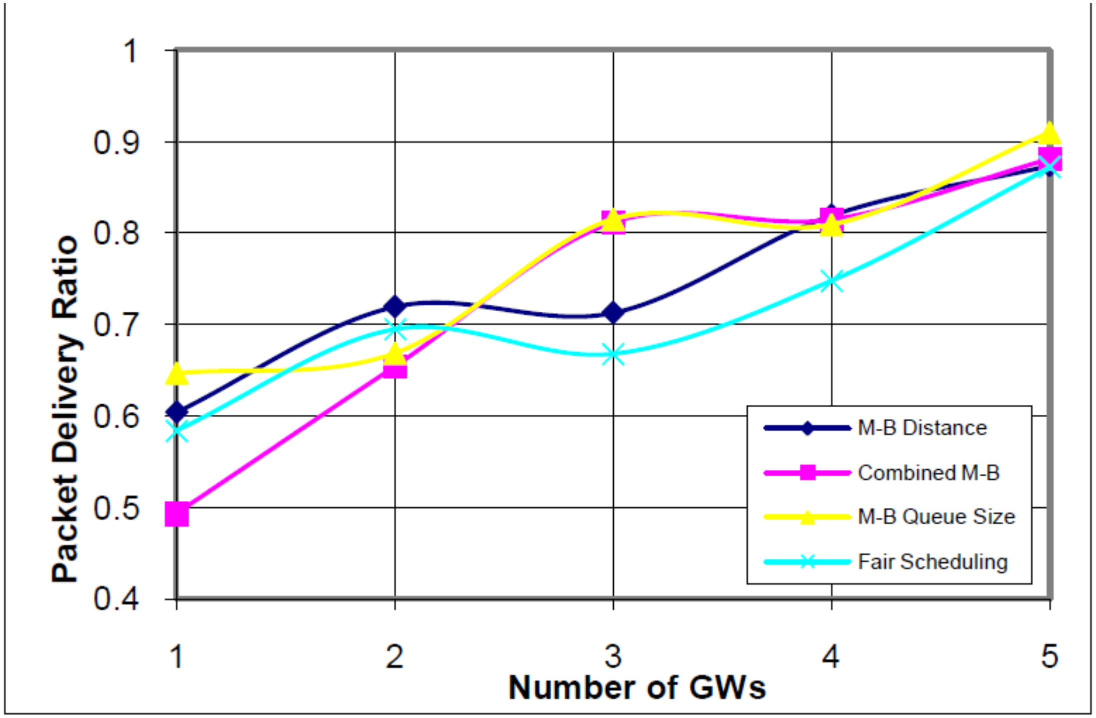

Figure 3 Average Packet Delivery Ratio, 250 Clients, 50 MR

Results & Discussion

- Delay is lower with M-B except in case with a single GW, due to GW bottleneck

- (in the TDMA approach, the GW is the co-ordinator of the schedule)

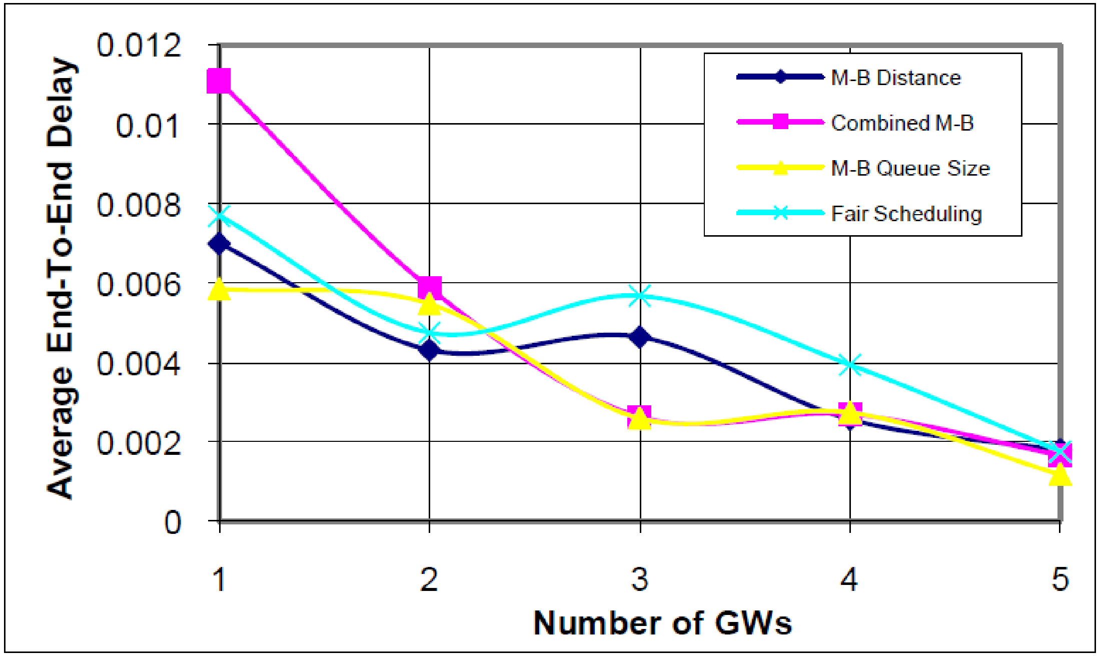

Figure 4 Average End-To-End Delay, 250 Clients, 50 MR

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Conclusions & Future Work

- Extension of existing mixed bias approach by applying cross-layering
- Proposed new combined mixed bias approach
- Initial results are promising for further investigation
- Investigate adapting parameters to network conditions

Combined Mixed Bias Scheduling

- Bias against multiple characteristics at once:

$$R = \gamma_1 R_1 + \gamma_2 R_2 + \gamma_3 R_3$$

- Where:

$$R_1 = \frac{\alpha_1}{c^{\beta_{11}}} + \frac{1-\alpha_1}{c^{\beta_{12}}}$$

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$$R_n = \frac{\alpha_n}{c^{\beta_{n1}}} + \frac{1-\alpha_n}{c^{\beta_{n2}}}$$

Thanks for Listening!

Questions?

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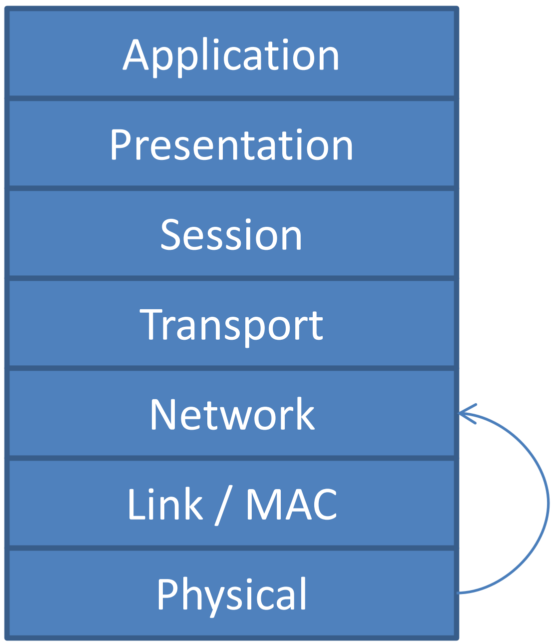
Cross Layering

OSI 7 Layer Stack

Cross Layering

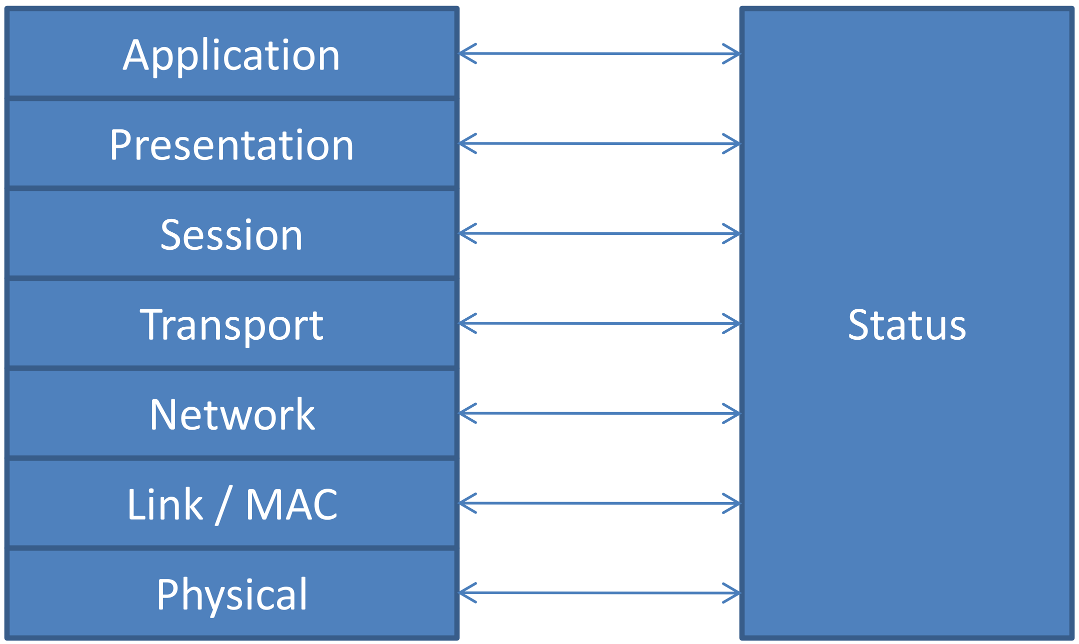


OSI 7 Layer Stack

Direct Communication:

- Layers which do not normally interact exchange information
- Difficult to maintain
- Poor extensibility

Cross Layering



OSI 7 Layer Stack

Status:

- Link quality
- Queue sizes
- Application requirements
- Distance between nodes

- Easily enable cross-layer interactions by querying the status stack