Cross-Layer Design for the Control of Ad hoc Networks

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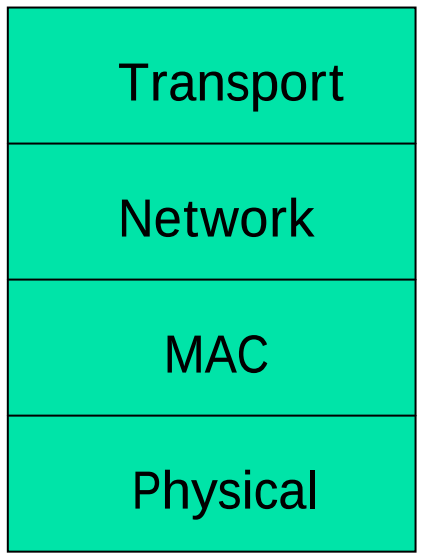
Cross-Layer Design

- Traditionally: networks designed according to a layered architecture
- Optimizing within layers has reached the point of diminishing returns.
- Future applications that will fuel the growth of wireless require orders of magnitude increases in performance.
- **Thesis:** To satisfy the increasing demand for new wireless services, a *cross-layer perspective* needs to be taken to obtain significant improvements in wireless spectrum efficiency



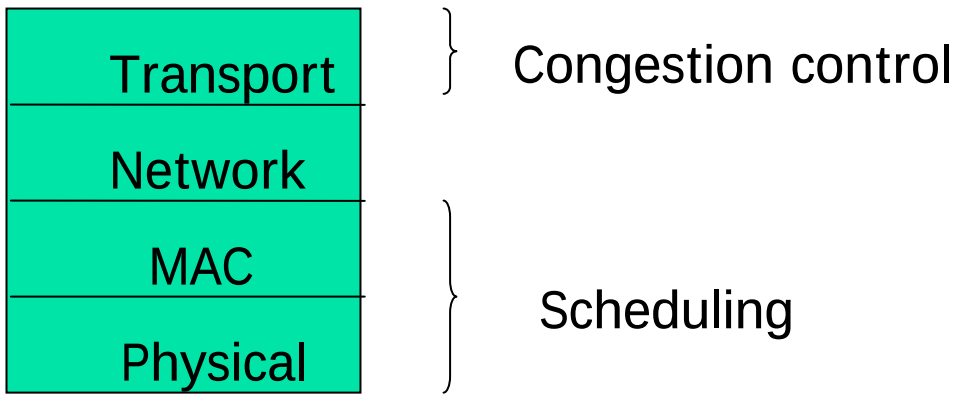
The Cross-layer Dilemma: Efficiency vs. Modularity

- Cross-Layer design needed to improve *efficiency*
- Layers are coupled
  - Potential loss of *modularity*
  - Could lead to complex and fragile overall design

- Propose: “Loose coupling”
  - Minimal interaction between layers
  - Imperfect measurements or decision at one layer should not affect entire system
  - Important to study the impact of imperfect decisions made at different layers on the overall solution

Example: The Cross-Layer Congestion-Control and Scheduling Problem

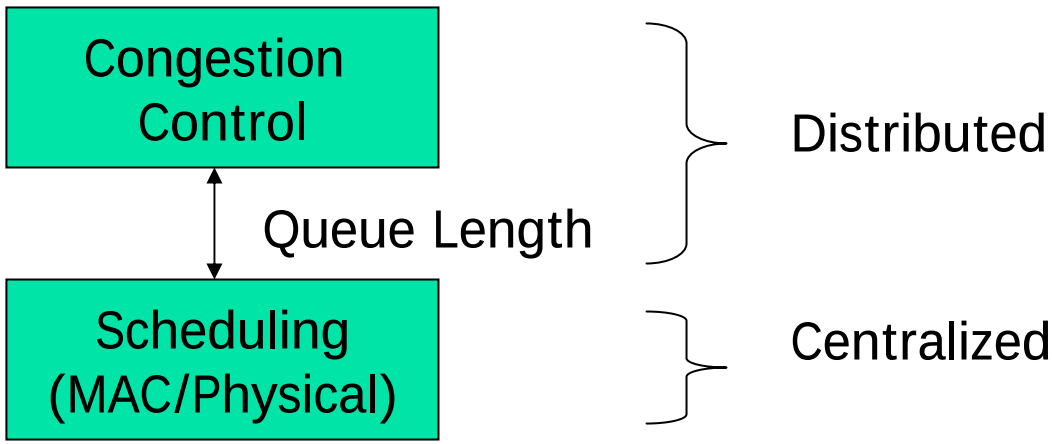
- **Rate control (congestion control)**: Determines end-to-end rate at which users should transmit
  - Maximize capacity and avoid excessive congestion
  - Improve fairness of the service to different users
- **Scheduling**: Everything in MAC and Physical layer, e.g., power control, link scheduling, adaptive modulation and coding
- **Goal:** To determine the maximum end-to-end rate at which users should transmit and at the same time find the associated "scheduling policy" that stabilizes the system.



- Can be formulated as a utility maximization problem subject to wireless physical layer constraints.

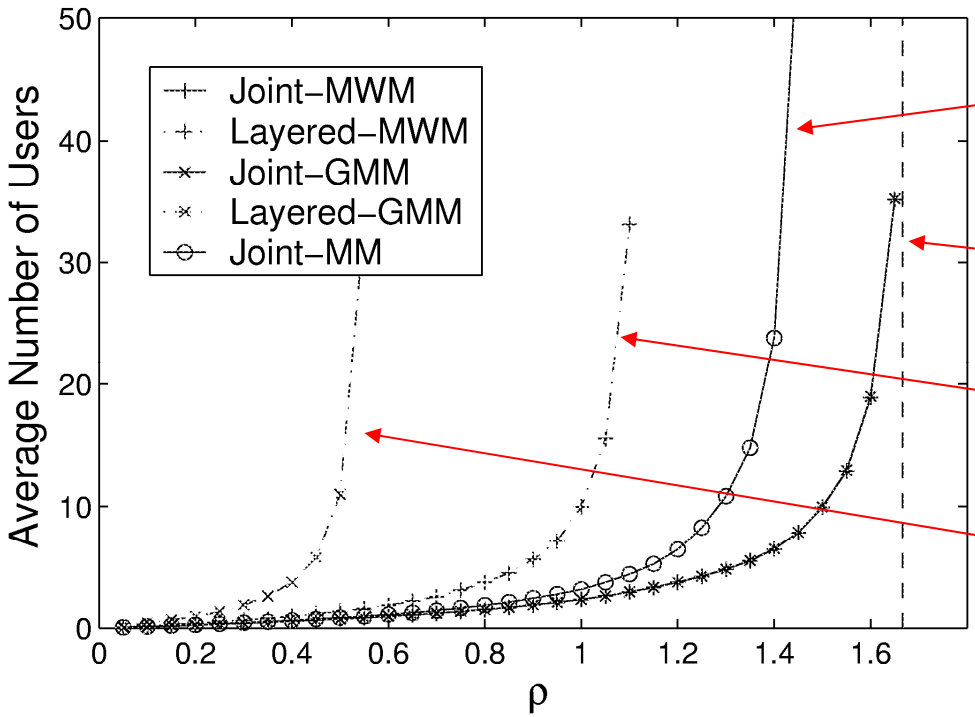
Comments on the Optimal Cross-Layer Solution

- Exhibits a *loose-coupling* property



- Imperfect scheduling solutions (necessary for distributed algorithms) result in provably graceful degradation.
- Preliminary results: Entirely distributed solutions for simple interference models.

Performance Comparison



Cross-Layer solution With MM

Cross-Layer solution With MWM or GMM

Layered solution With MWM

Layered solution With GMM

MM: Maximal Matching (Distributed) GMM: Greedy Maximal Matching (centralized)

MWM: Maximum-Weighted Matching (optimal centralized)

Cross-layer solution with simple (*imperfect*) scheduling outperforms layered solution with complex (*perfect*) scheduling

Conclusion and Future Work

- Optimization framework can be used to incorporate energy, capacity, fairness, priority, multi-path, etc.
- **Potential:** cross-layer gains are *multiplicative*
- **Key to Success:** Cross-layer solutions should be *loosely coupled* across the layers such that *high performance* gains are achieved without a significant loss of *modularity*.
- ***Open Questions:***
  - Developing *distributed solution* for *general interference models* with *provably efficient* properties.
  - Incorporating the effects of delay in the feedback
  - Developing cross-layer solutions for random access MAC
  - Tailoring solutions to mobility