A Framework for Cross-layer Design of Energy-efficient Communication with QoS Provisioning in Multi-hop Wireless Networks

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Outline

- Introduction
- Proposed Algorithms
- Simulation
- Conclusion and future work
- Reference

Introduction

- Efficient use of energy while providing an adequate level of connection to individual sessions is of paramount importance in multi-hop wireless networks
- Nevertheless, the primary goal of a communication network is to deliver an acceptable level of communication network
- QoS guarantees

Introduction

- QoS have different interpretations at different communication layers
  - Physical layer：
    - bits error rate (BER)
  - MAC layer ：
    - minimum rate/maximum delay
  - Network layer：
    - end-to-end provisioning of the guarantee QoS for each session
- Minimum short-term rate requirements and maximum tolerable BERs of the session

Introduction

- Interaction among these layers
  (Physical layer, MAC layer, network layer)
- Physical layer
  - Transmit power, modulation level, coding rate, antenna beam coefficients.
  - Restraints both routing and MAC decisions by altering the directed topology graph, feasible transmission schedules, and payload transmission rates
- MAC layer
  - Responsible for scheduling the transmissions and allocating the wireless channels
  - As a result of transmission schedules, high packet delays and/or low bandwidth can occur, forcing the routing layer to change its route decision

Introduction

- Network layer
  - Select the wireless link that will eventually carry the data packets
  - Different routing decisions alter the performance of MAC layer
- Cross layer design.

Proposed algorithms

- Assumption
  - The routes are already given.
  - Point-to-point transmissions and no node is permitted to send multiple packets (for the same receiver or not) at the same time

Proposed algorithms

- Transmission rate

$$R(l) = \frac{b_{sym}^{l} \times R_c^{l}}{T_{sym}^{l}} \qquad (1)$$

b_{sym}^{l} is the number of bits per symbol

R_c^{l} is the coding rate T_{sym}^{l} is the symbol duration for the transmissions over l

$$\gamma_l = \frac{b_{sym}^{l} \times R_c^{l}}{L \times T_{sym}^{l}} \qquad (2)$$

γ_l is the constant payload rate for each slot on link l

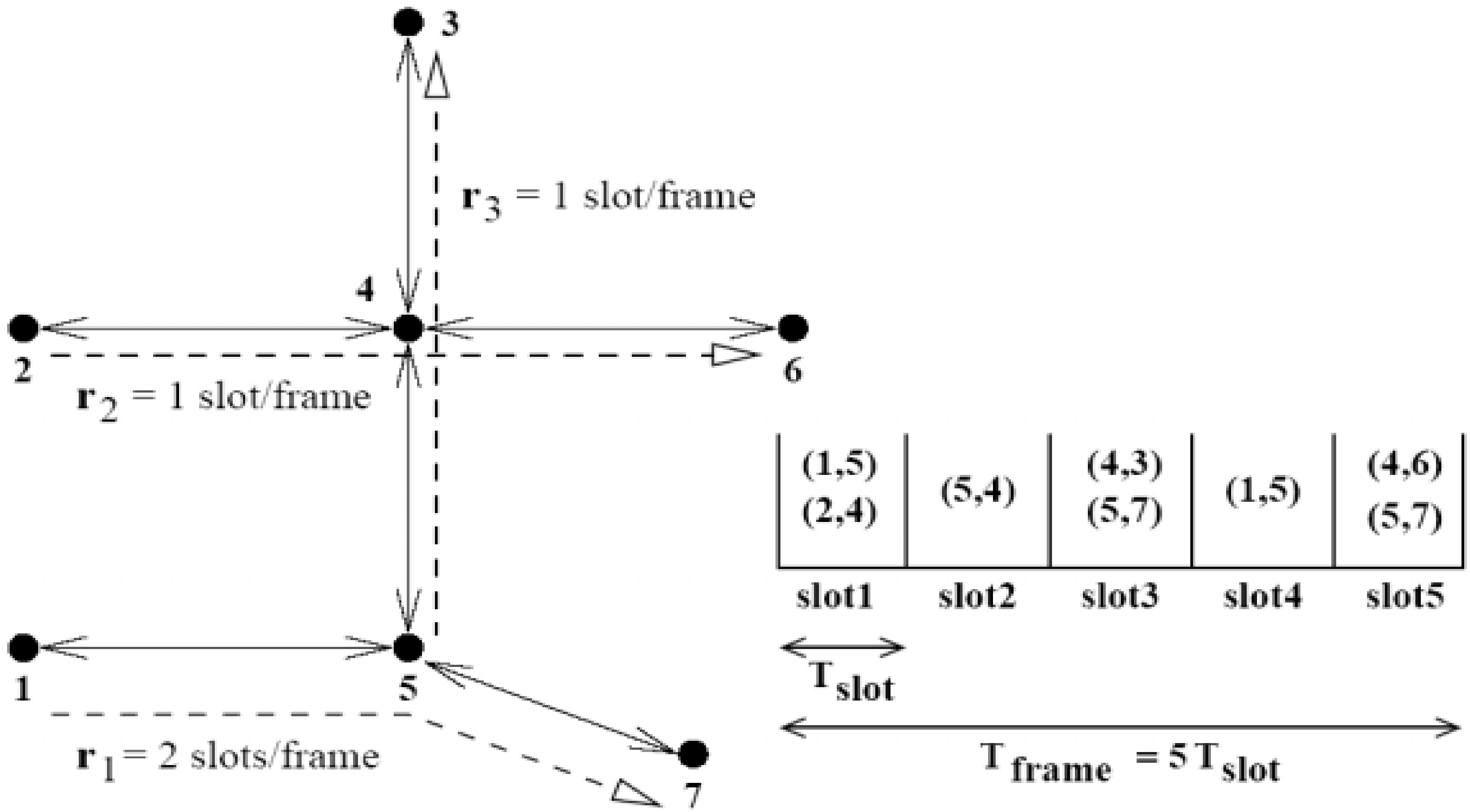
$$k_i^l = \left\lceil \frac{r_i}{r_l} \right\rceil \qquad (3)$$

r_i is the short-term requirement of each session i

k_i^l is the actual number of times slots assigned to a directed link l of session i

- Virtual Links

Proposed algorithms



Proposed algorithms

- BER

M is the modulation level
$\in$ is a maximum acceptable BER

$$SINR \geq \frac{-\ln(5 \in)}{1.5}(M-1)$$

$$\frac{G_{T(l)R(l)}P_l}{\sum_{\substack{j \neq i \\ j \in C(n)}} G_{T(j)R(l)}P_j + \sigma^2_{R(l)}} \geq \gamma_l; \forall l \in C(n)$$

$$P \geq G\tilde{P} + \beta$$

Proposed algorithms

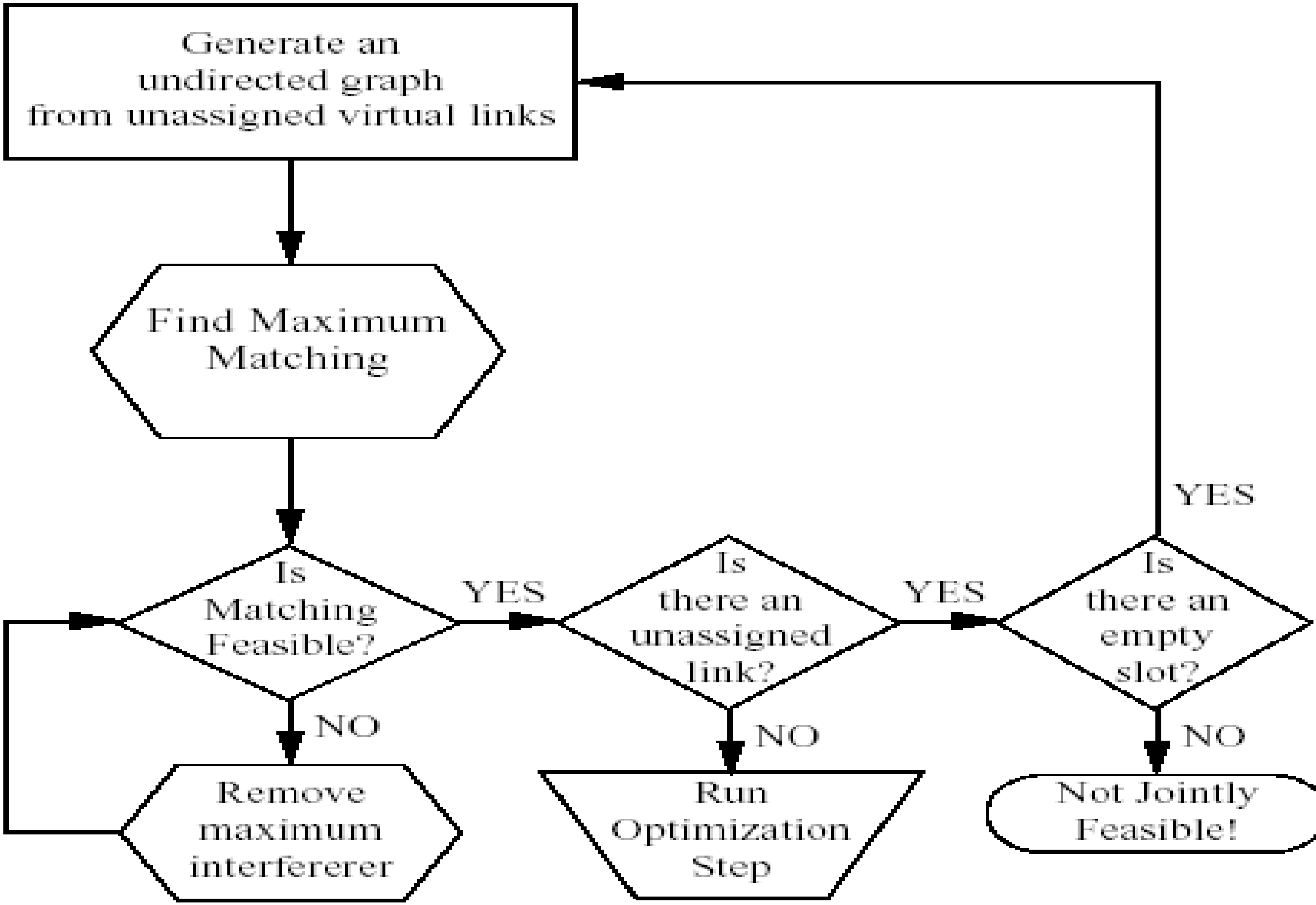


Fig. 2. Block Diagram for Algorithm A.

Proposed algorithms

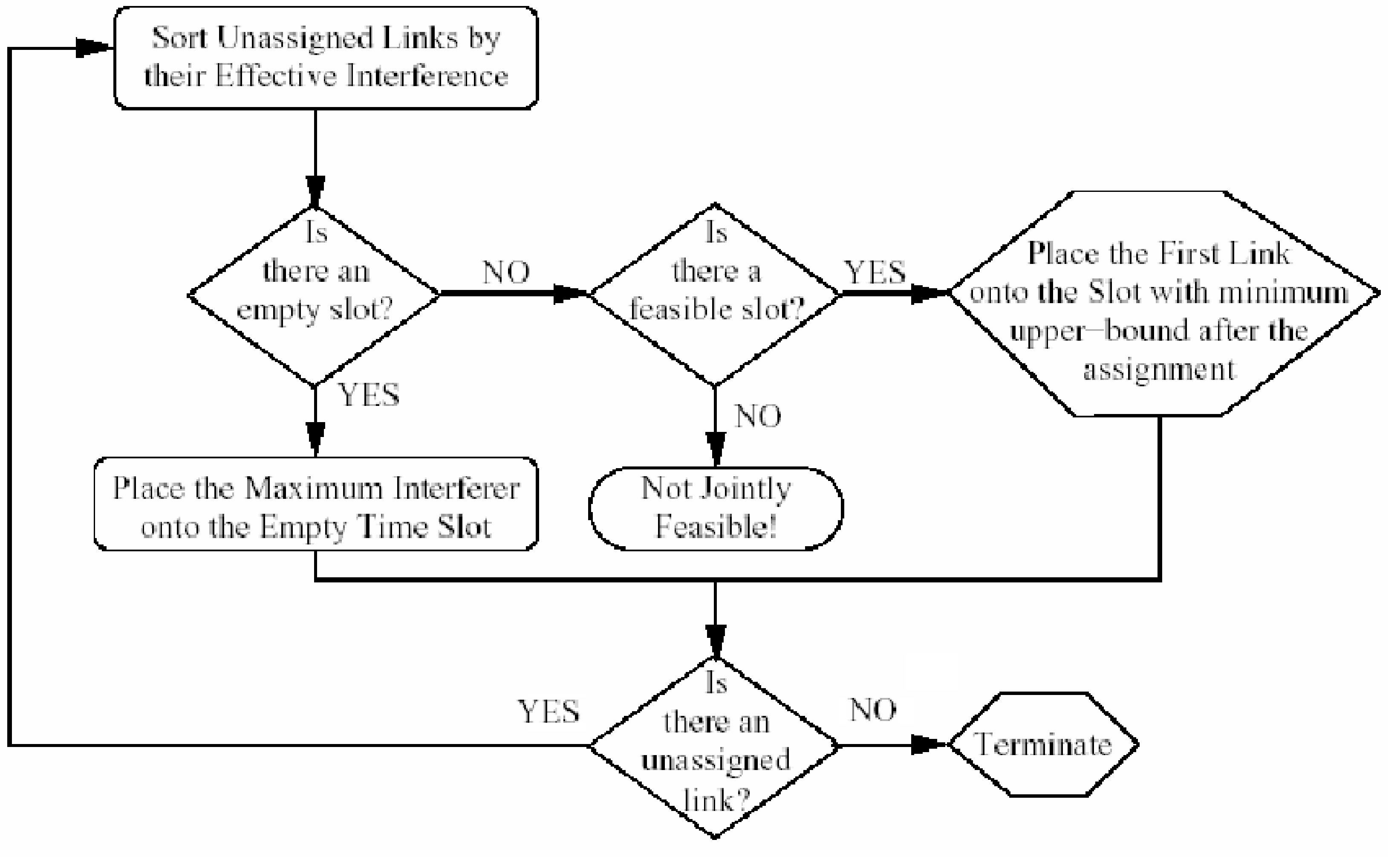
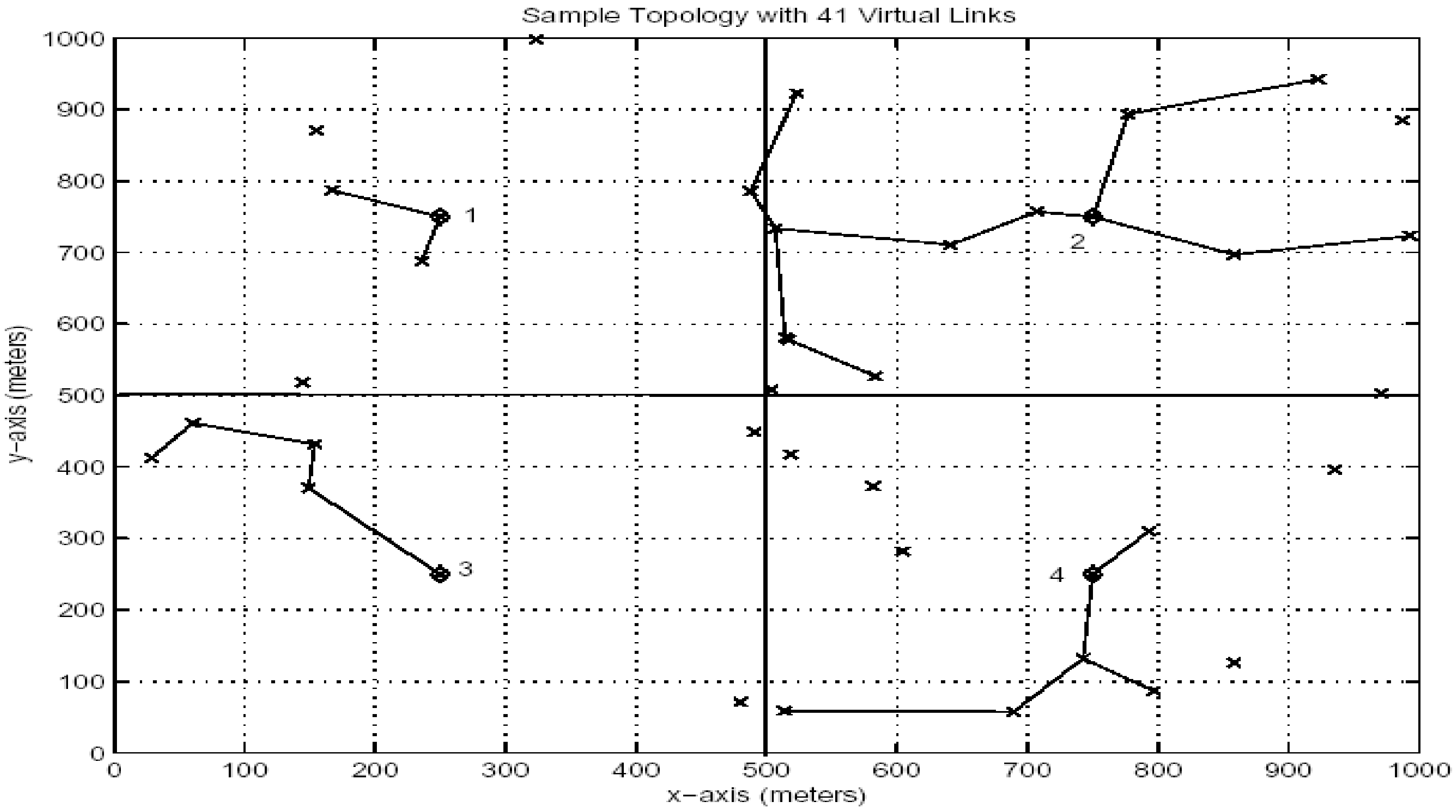


Fig. 3. Block Diagram for Algorithm B.

Simulation



Sample Topology with 41 Virtual Links
1000
900
800
700
600
500
400
300
200
100
0
y-axis (meters)
0
100
200
300
400
500
600
700
800
900
1000
x-axis (meters)
1
2
3
4

Simulation

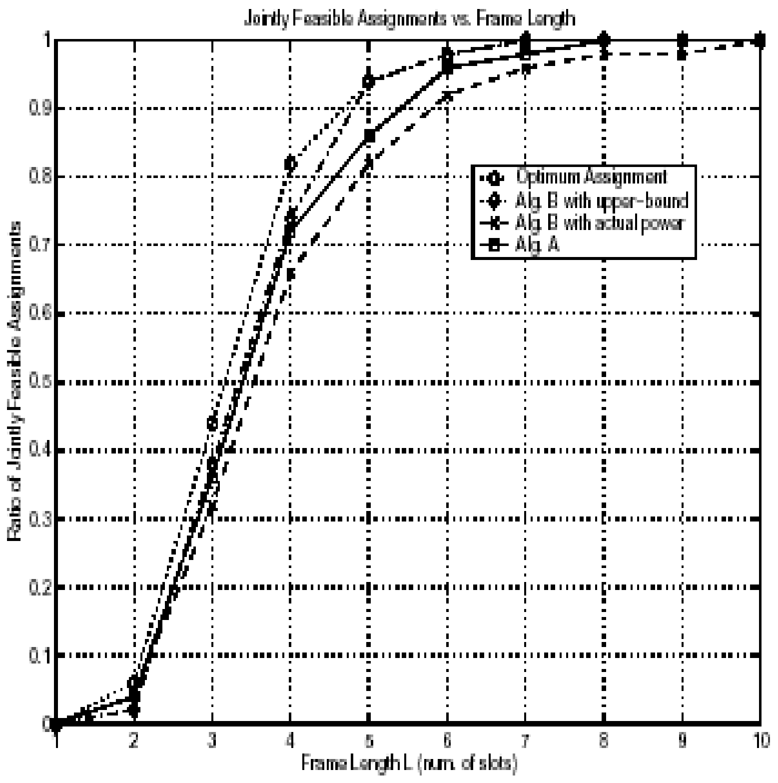


Fig. 5. Ratio of jointly feasible scenarios for 7 sessions and minimum-hop routing.

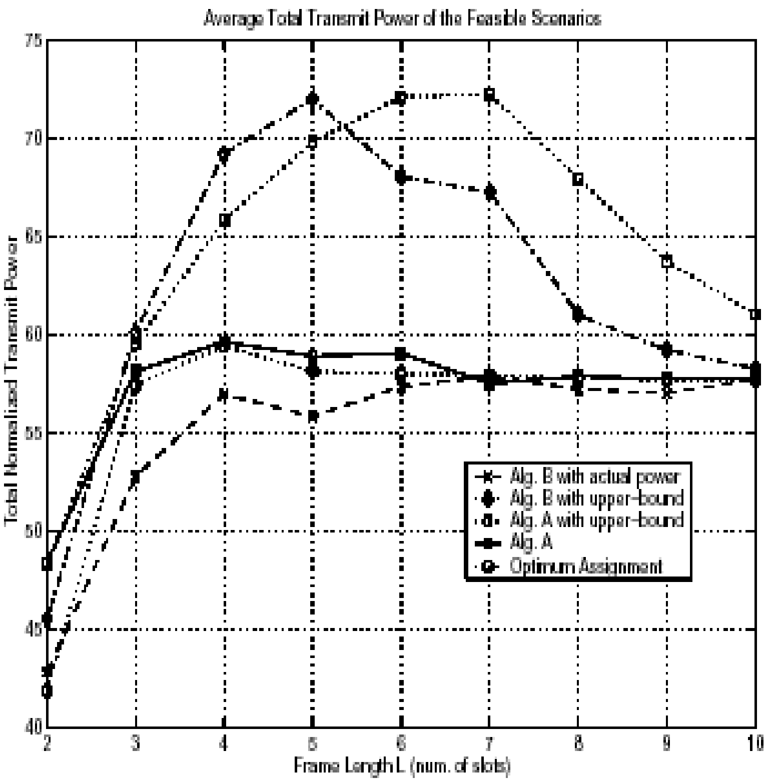


Fig. 6. Total transmit power averaged over the jointly feasible scenarios for 7 sessions and minimum-hop routing.

Simulation

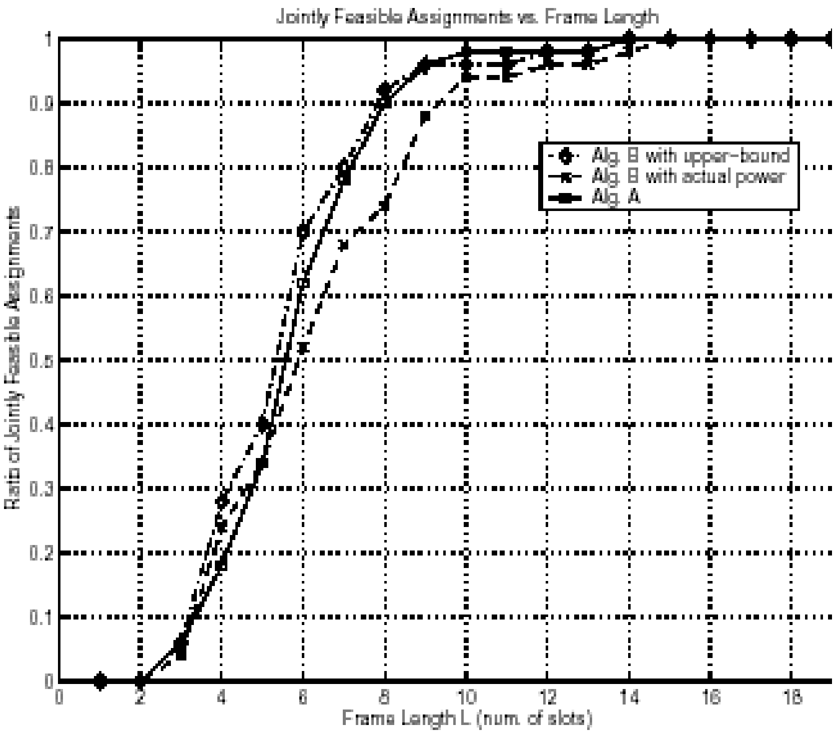


Fig. 7. Ratio of jointly feasible scenarios for 7 sessions and minimum routing.

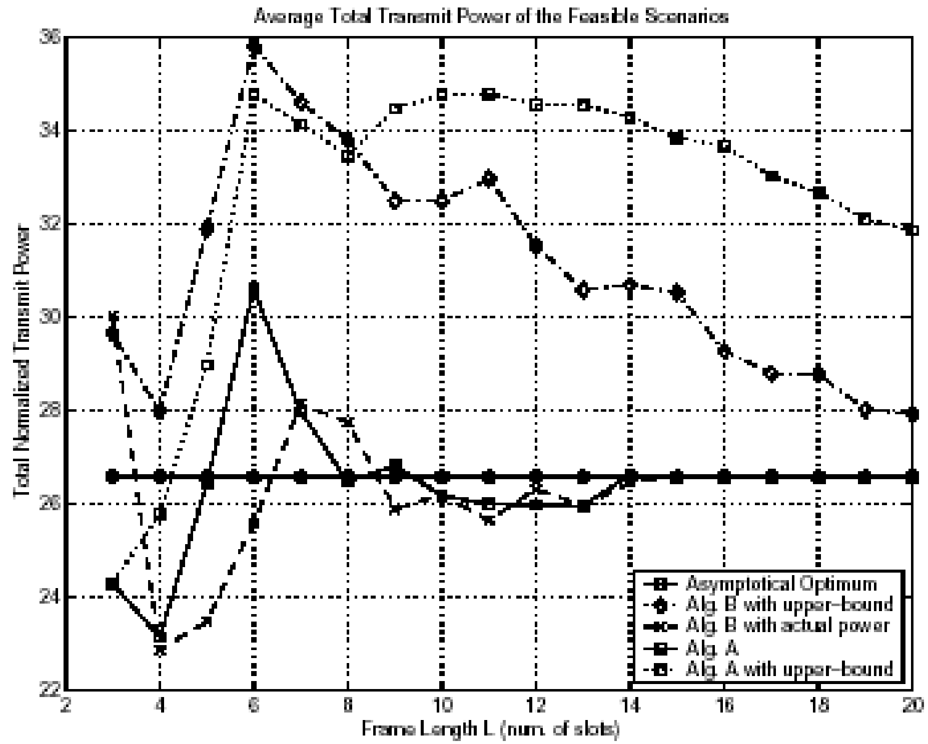


Fig. 8. Total transmit power averaged over the jointly feasible scenarios for 7 sessions and minimum-power routing.

Simulation

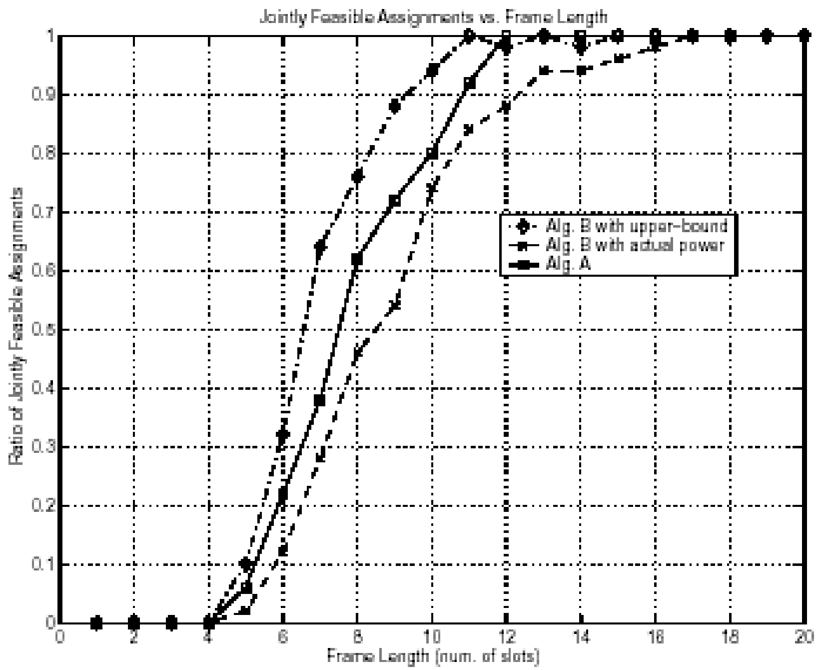


Fig. 9. Ratio of jointly feasible scenarios for 15 sessions and minimum-hop routing.

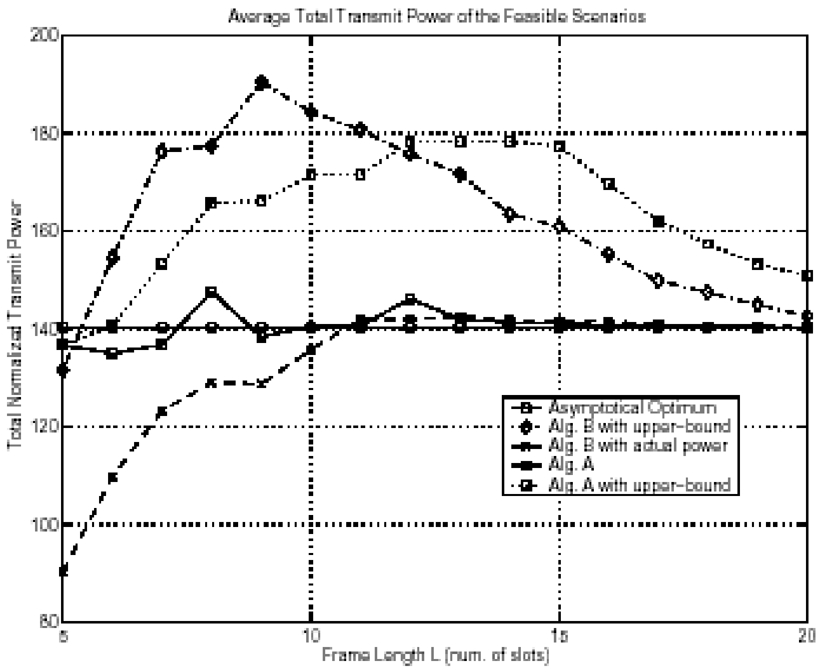


Fig. 10. Total transmit power averaged over the jointly feasible scenarios for 15 sessions and minimum-hop routing.

Conclusion and future works

- A top-down design strategy such as first sloving the feasibility problem, then minimizing the power consumption performs better in terms of the objective function
- The water-filling argument outperforms the top-down design strategy in finding a feasible solution
- Routing layer plays a dominant role in reducing power consumption, but it happens at the expense of QoS provisioning

Conclusion and future works

- Try to find a distributed algorithm based on local information
- Try to design the really cross-layer mechanism that jointly performs routing, scheduling, and power control.
- Anycasting services
- Finding the performance limits of wireless multi-hop networks

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