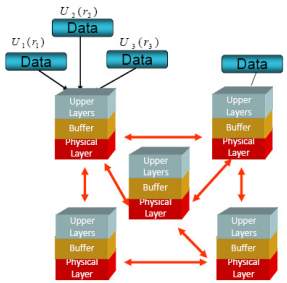
WNUM

Dan ONeill, Andrea Goldsmith, Stephen Boyd

Overview and Problem Statement 1/9

- Seek optimal network control policies in random environments
- WNUM Optimizes tradeoffs
  - Rate
  - Delay
  - Reliability
- Yields adaptive policies
- Learns the channel



Optimal Network Control Policies 2/9

- Functions that control network resources
- Inputs
  - Random network channel information G^k
  - Parameters λ^k
  - Other policies
- Outputs estimates of resource values
  - Optimize performance
  - Meet constraints

$G \in R^{LxL}$	Channel Matrix
$S(G) \in R^L$	Link Power
$R(S(G),G) \in R^L$	Link Rate
$r(G) \in R^M$	Information Rate
$\theta(G) \in R^L$	Code Rate
$\lambda_q \in R^L$	Queue Length
$\lambda_s \in R^L$	Power Cost

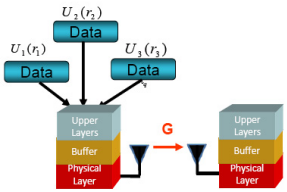
Example Formulation 3/9

$$\begin{aligned}
\max \quad & E\sum_m U(r_m(G),\phi_m(G)) \\
\text{subject to} \quad & \\
& E[S_l(G)] \le \bar{S}_l \qquad l = 1,\ldots,L \\
& E[Ar] \le E[Diag(\theta(G))R(S(G),G)] \\
& E[\phi(G)] \le 1 - E[A^T \vartheta(\theta(G))] \\
& 0 \le \theta(G) \le 1 \\
& 0 \le \phi(G) \le 1
\end{aligned}$$

Distribution of G is assumed unknown

Downlink: Uncoded Rate-Delay-Reliability 4/9

- Policies
  - Information rate r()
  - Tx power S()
  - Tx Rate R()
- Policy adapts to
  - Changing channel conditions (G)
  - Packet backlog λ_q
  - Historical power usage λ_S



Downlink: Uncoded Rate-Delay-Reliability 5/9

- Policies

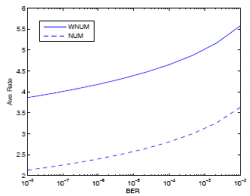
$$S(G^k,\lambda^k) = \begin{cases} \left(\frac{\lambda_q^k}{\lambda_s^k} - \frac{N}{G^k}\right) & \frac{\lambda_q^k}{\lambda_s^k} < \frac{G^k}{N} \quad \lambda_q,\lambda_s^k > 0 \\ 0 & \text{otherwise} \end{cases}$$

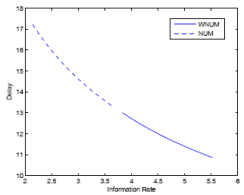
$$R(G^k,\lambda^k) = \begin{cases} \log\left(1 + K\frac{\lambda_s^k}{\lambda_s^k}\frac{G^k}{N}\right) & \frac{\lambda_s^k}{\lambda_q^k} < \frac{KG^k}{N} \quad \lambda_s^k > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$r(G^k,\lambda_q^k) = r(\lambda_q^k) = [\dot{U}]^{-1}(\lambda_q^k)$$

k is sample index

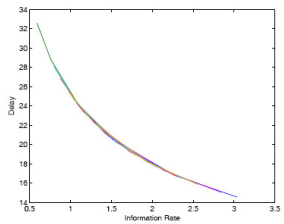
Downlink: Uncoded Rate-Delay-Reliability 6/9





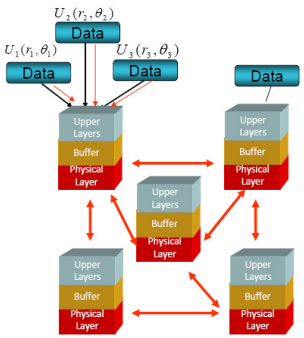
MANET: Rate-Reliability-Tradeoff 7/9

- Multi-hop, routed network
  - Interfering links
  - Infinite buffers
- Random channel matrix G
- Policies for
  - Link power $S_l(.)$ l=1,…,L
  - Link rates $R_l(.)$ l=1,…,L

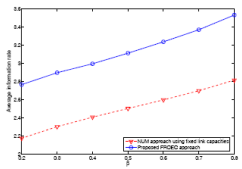


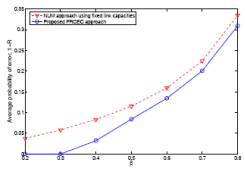
MANET: Explicit Rate-Reliability Control 8/9

- Utility functions U(r)
  - Rate only
  - Does not "select" Rate-Reliability operating point
- Explicit Rate-Reliability tradeoff by sources
  - U_B(rate, reliability)
    - B controls tradeoff
  - Sources select link code rate to meet reliability needs
- Policies for
  - Link power $S_l(.)$ l=1,…,L
  - Link rates $R_l(.)$ l=1,…,L
  - Code rates $\theta_l()$ l=1,…,L



MANET: Explicit Rate-Reliability Control 9/9





Beta controls tradeoff in U_B(rate, reliability)