Congestion Control in Wireless Networks

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Motivation

- **Wired Networks**
  - Packet loss only due to traffic congestion
  - TCP widely used for congestion control

- **Wireless Networks**
  - Congestion and Channel Fading both contribute to packet loss
  - *Why distinguish?*: Both have different statistics

Thus, TCP needs to be revisited for use in wireless networks

*'Control'*ling Congestion

- Route Incidence matrix $[[R_{li}]]$, Transmission Rates $x_i(t)$, Link Prices $p_l(t)$

$$\begin{aligned} y_l(t) &= \sum_i R_{li} x_i(t) \\ q_i(t) &= \sum_l R_{li} p_l(t) \end{aligned}$$

- Control Mechanism (State Space formulation)
  - Adapt the rates $x_i(t)$ based on *feedback* $q_i(t)$ (*e.g.* TCP window control)

$$\begin{aligned} \dot{z}_i &= F_i(z_i, q_i) \\ x_i &= G_i(z_i, q_i) \end{aligned}$$

  - The link prices $p_l(t)$ change depending on $y_l(t)$ (*e.g.* AQM)

$$\begin{aligned} \dot{v}_l &= H_l(v_l, y_l) \\ p_l &= K_l(v_l, y_l) \end{aligned}$$

*‘Control’*ling Congestion (*contd...*)

- Can be interpreted as a Utility Maximisation Problem *i.e.*

$$max_{\mathbf{x}\geq\mathbf{0}} \sum_i U_i(x_i)$$

$$\text{subject to } R\mathbf{x} \leq \mathbf{C}$$

  where, $\mathbf{C}$ is the link capacity vector

- Different variants of TCP have different utility functions, and different rate and link price control mechanisms
- *e.g.* TCP Reno

$$U_i(x_i) \quad = \quad \frac{\sqrt{2}}{\tau_i} \tan^{-1}(\frac{\tau_i x_i}{\sqrt{2}})$$

Modification for Wireless Networks

- Link Capacities C_l *random* functions of time
- Need to track channel variations and take appropriate action
- A possible approach uses dependence of $\mathbf{C}$ on transmit power P
- Thus, modified optimisation problem with additional optimisation variable P

$$\begin{array}{rc} max_{\mathbf{x} \geq \mathbf{0}} & \sum_i U_i(x_i) \\ \text{subject to} & R\mathbf{x} \leq \mathbf{C}(\mathbf{P}) \\ & P_l \leq P_{l,max} \ \forall l \\ & \mathbf{P}, \mathbf{x} \geq \mathbf{0} \end{array}$$

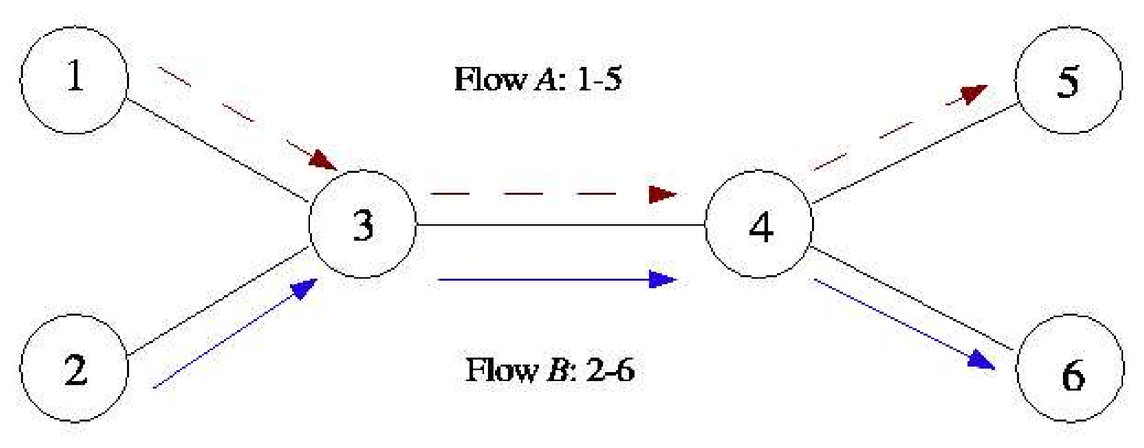
- Chiang and Man, break up the above into two separate optimisations

$$\text{maximise}_{\mathbf{x} \geq \mathbf{0}} \ \sum_s U_s(x_s) - \sum_s \sum_{l \in L(s)} p_l x_s$$

$$\text{maximise}_{\mathbf{P_{max}} \geq \mathbf{P} \geq \mathbf{0}} \ \sum_l p_l C_l(\mathbf{P})$$

Simulation Environment

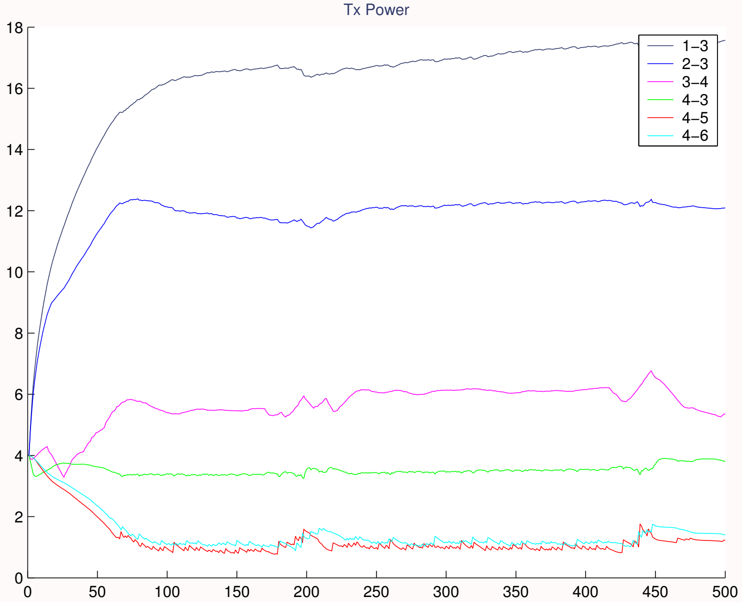
- Topology



- Node: TCP Reno agent whose transmission power can be controlled
- Link: Wireless channel with SIR dependent capacity
- Link: Finite transmission buffer & log-normal channel gain
- Queueing delay and Propagation delays also simulated
- Packet loss either due to buffer overflow (congestion) or due to fading

Results

Start Tx Power	With Power Control	Without Power Control
1	298	220
2	295	228
3	296	221
4	308	233
5	297	162



Results (Contd.)

- Currently experimenting with Network Simulator (NS-2) and trying to understand its functioning and limitations
- Also, looking up more literature on distinguishing between traffic and channel variation statistics
- Will simulate the above formulation and evaluate the performance

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