Mutliple Access and Flow Control

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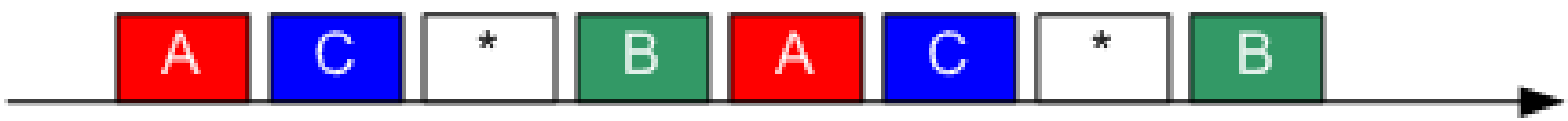
Three Ideas

- A Zero-Collision MAC Protocol [Jiwoong Lee]
  - Variable-Length Packets
  - Quick Convergence
  - Should work over WiFi hardware
- A Fair MAC Protocol [Libin Jiang]
  - Achieves short-term fairness
- Decentralized MAC/Flow Control [Libin Jiang]
  - Maximizes Social Welfare (almost)

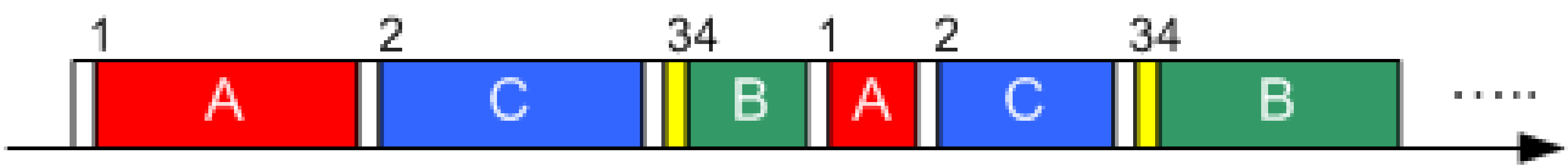
Zero-Collision MAC Protocol [Jiwoong Lee]

- Example: Three nodes (A, B, C)
- Assume system is designed for up to 4 nodes
- Nodes choose a different number in {1, 2, 3, 4}
- Say A = 1, B = 4, C = 2
- Nodes transmit in order: AC*B, AC*B, … [* = idle]

TDM:

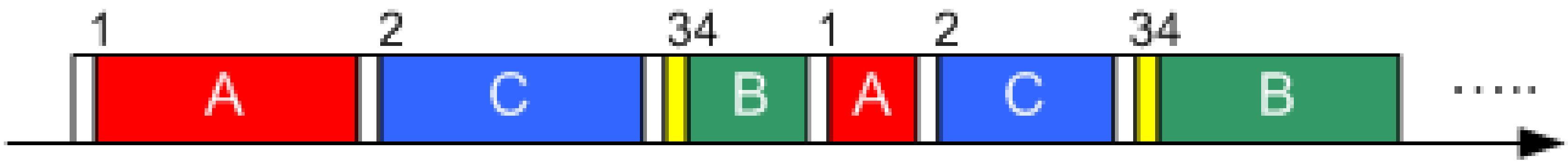


ZC:



Zero-Collision MAC Protocol [Jiwoong Lee]

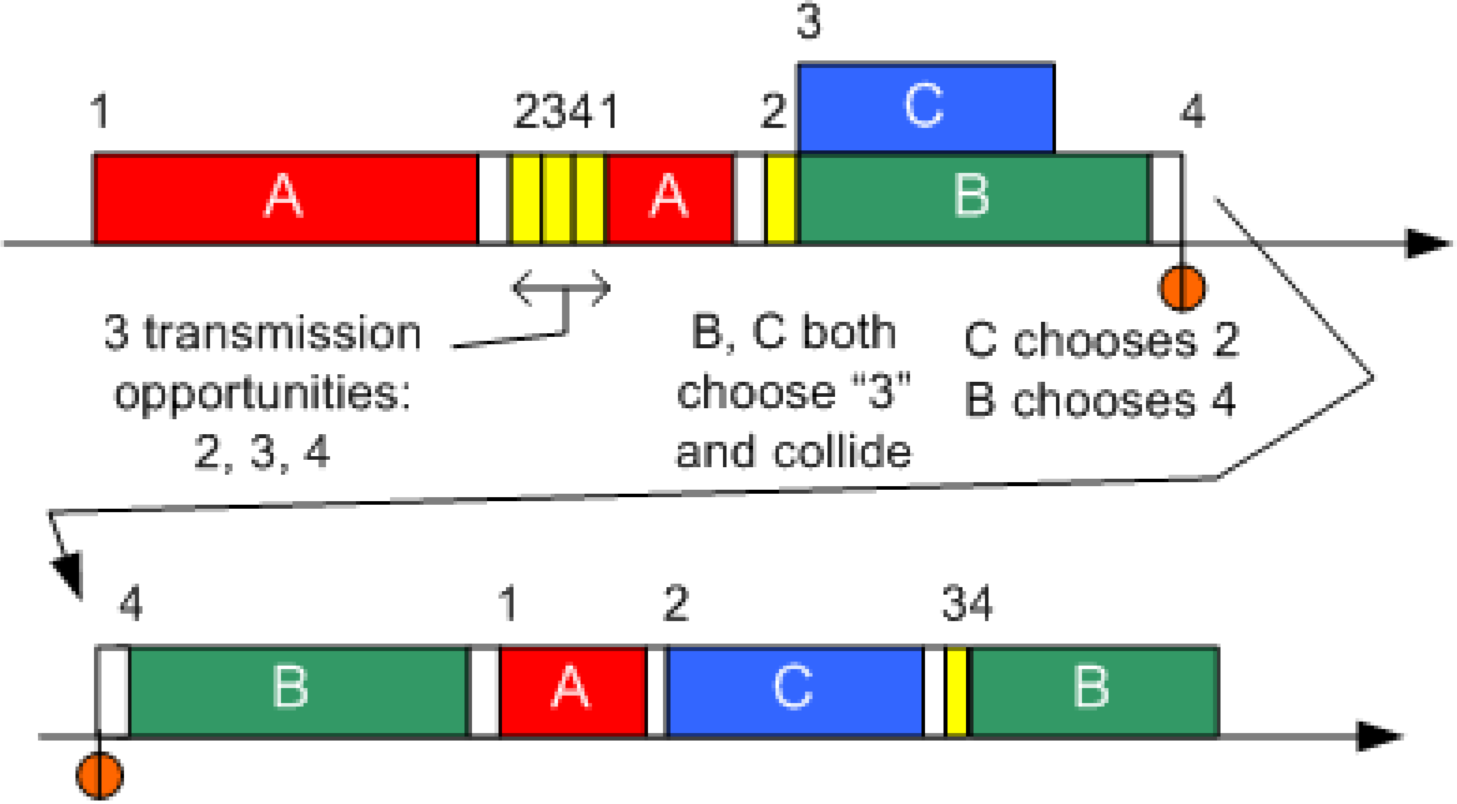
- Thus: AC*B, AC*B, ...



- If C skips a turn: A**B, AC*B, ...

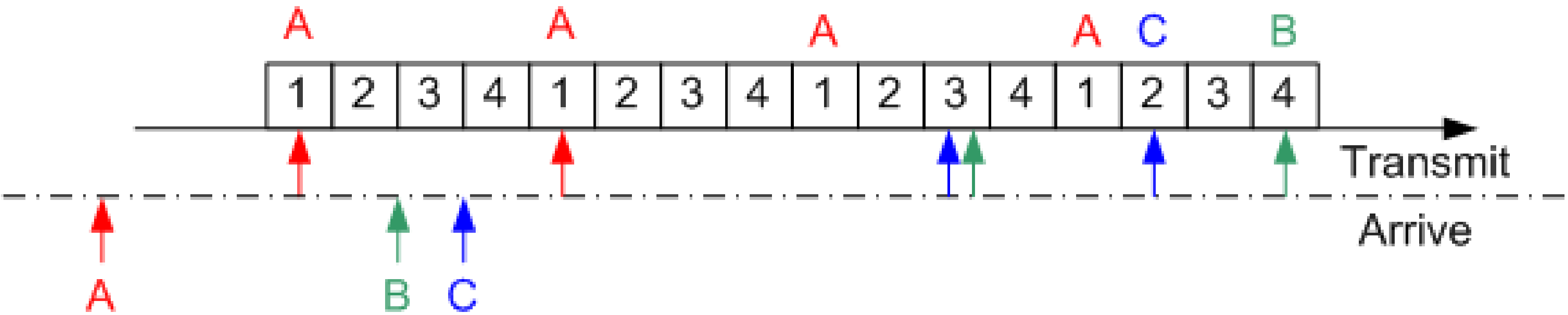
Zero-Collision MAC Protocol [Jiwoong Lee]

- Slot selection:
  - Try a free slot
  - If collide, try another free slot



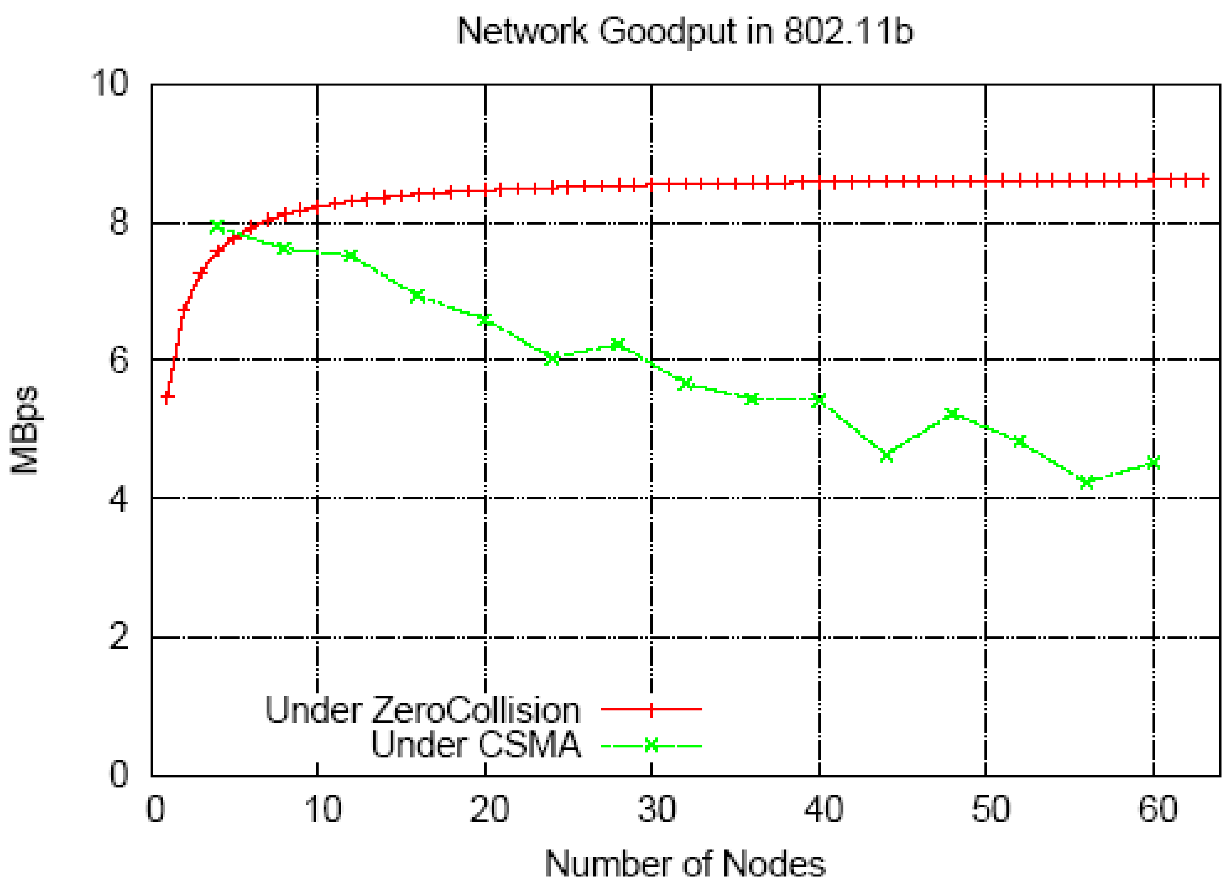
Zero-Collision MAC Protocol **[Jiwoong Lee]**

- Focusing on the slot selection process:

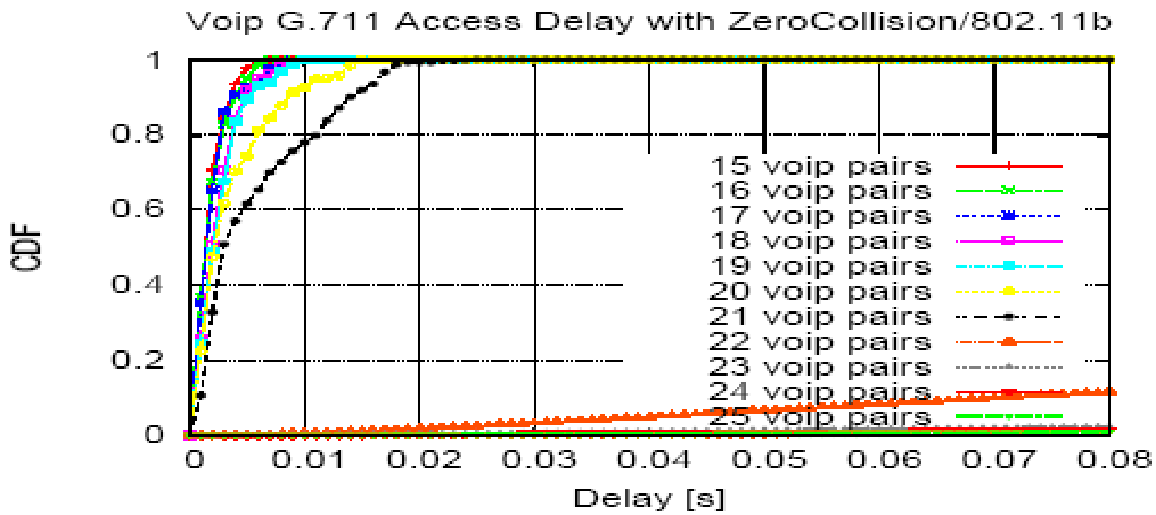


- This selection converges quickly
- One station may have more than one slot (e.g., AP)
- The number of slots can be adapted to demand
- Low jitter, efficient

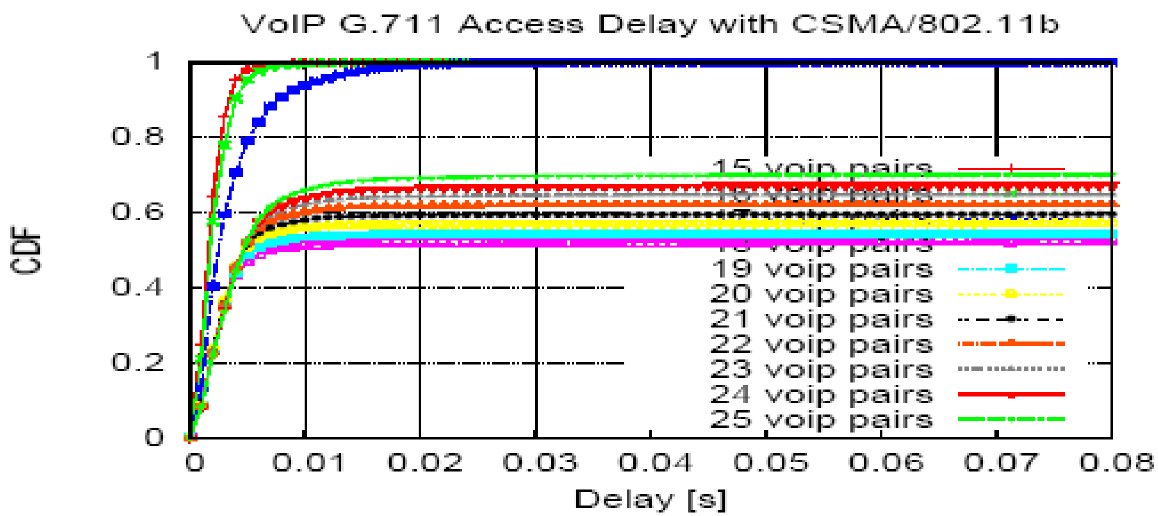
Zero-Collision MAC Protocol [Jiwoong Lee]



Zero-Collision MAC Protocol [Jiwoong Lee]



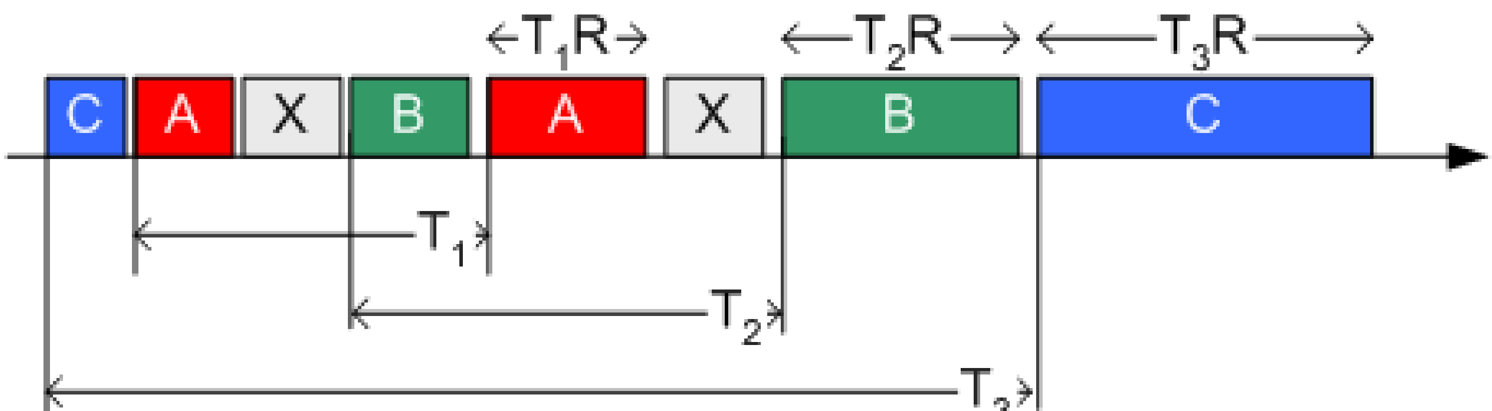
(a) ZC



(b) CSMA

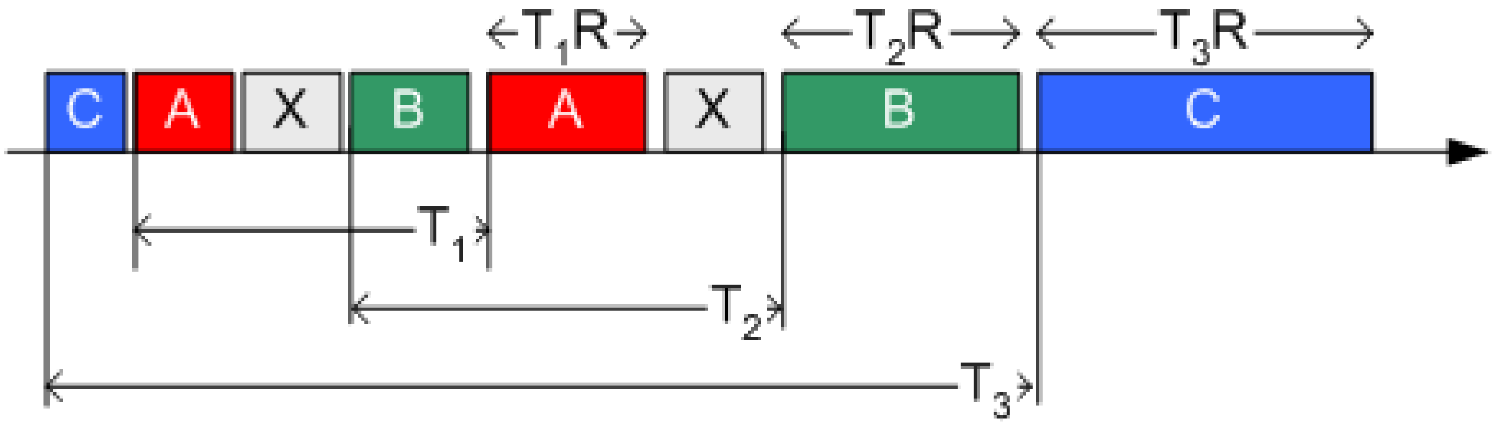
A Fair MAC Protocol [Libin Jiang]

- Basic Ideas:
  - Multiple access is random
  - This results in short-term unfairness
  - For improved fairness, let a node transmit in proportion to its waiting time (measured in "virtual slots")
    - A "virtual slot" is a transmission or a collision
  - Thus: wait T virtual slots→ transmit T.R bits



$T_1=3$; $T_2=3$; $T_3=7$

A Fair MAC Protocol [Libin Jiang]

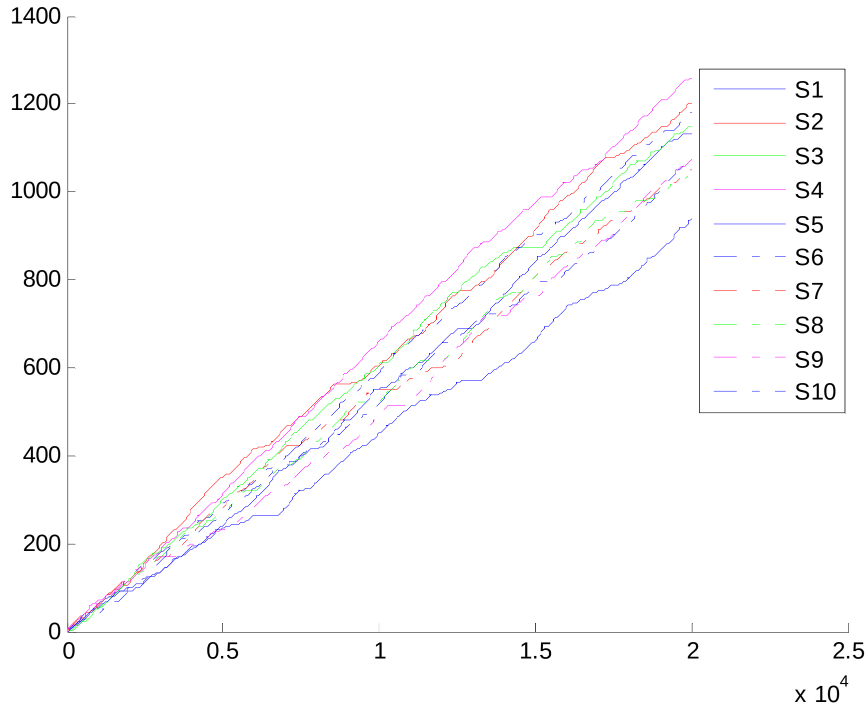


T_1=3; T_2=3; T_3=7

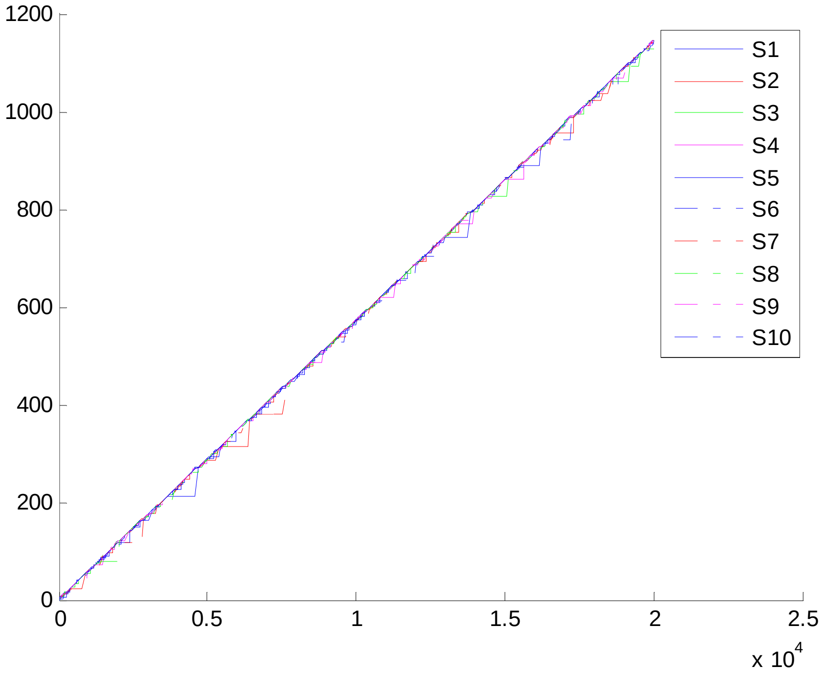
- Within a period of N virtual slots, each node transmit (about) N.R bits
- One can introduce different weights ….

A Fair MAC Protocol [Libin Jiang]

- Short-Term Fairness:



CSMA



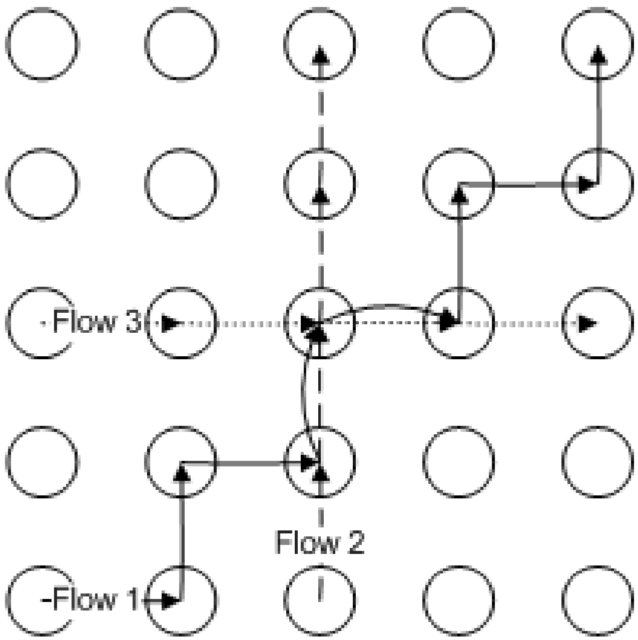
New Protocol

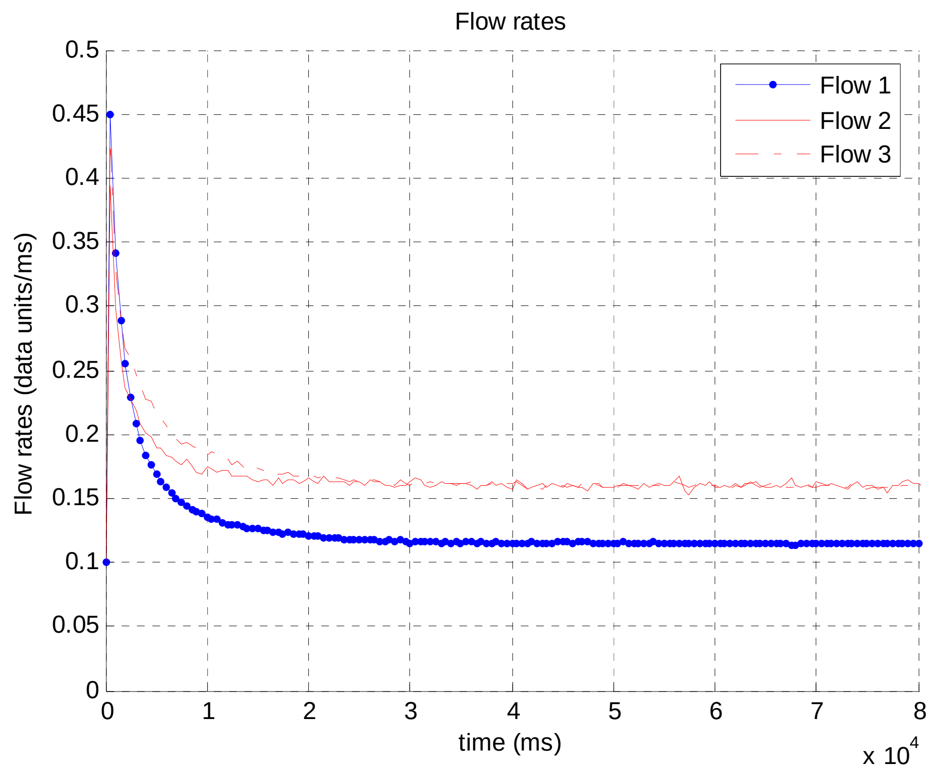
Decentralized MAC/Flow Control [Libin Jiang]

- Goal: Maximize total utility in Ad Hoc network
- Mechanism: Adjust backoff times based on difference in backlogs between sender and receiver
- Details: Consider a link from A to B
  - Waiting time at A is exponential with rate R
  - Rate R = exp{r}
  - $r(n) = \alpha[Q(A,n) - Q(B,n)]$
  - Q(A, n) is backlog at A for B at time n ….
  - α is a step size
  - At ingress G: adjust input rate according to Q(G)

Decentralized MAC/Flow Control [Libin Jiang]

- Example





Theoretical optimal flow rates for the three flows are 0.1111, 0.1667 and 0.1667

Decentralized MAC/Flow Control [Libin Jiang]

- Details:
  - We design distributed algorithm to solve

$$
\begin{array}{ll}
\max_{\mathbf{u},\mathbf{s},\mathbf{f}} & -\sum_{i=1} u_i \log(u_i) + \sum_{m=1}^{M} v_m(f_m) \\
\text{s.t.} & s_{km} \geq 0, \forall k, m : a_{mk} = 1 \\
 & s_{km} \geq s_{up(k,m),m}, \forall m, k : a_{mk} = 1, k \neq \delta(m) \\
 & s_{km} \geq f_m, \forall m, k : k = \delta(m) \\
 & \sum_i u_i \cdot x_k^i = \sum_{m:a_{mk}=1} s_{km}, \forall k \\
 & u_i \geq 0, \sum_i u_i = 1
\end{array}
$$

  - The actual Network-Utility-Maximization is (subject to the same constraints)

$$
\max_{\mathbf{u},\mathbf{s},\mathbf{f}} \sum_{m=1}^{M} v_m(f_m)
$$

Decentralized MAC/Flow Control [Libin Jiang]

- Details (continued):

The distributed algorithm is composed of

- Maximal backpressure
  - Each link k always serve the flow with the maximal backpressure z_k

$$z_k = \max_{m:a_{mk}=1}(q_{km} - q_{down(k,m),m})$$

- CSMA scheduling
  - Link k sets $r_k = z_k$
- Rate control by the sources

$$\max_{f_m}\{v_m(f_m) - q_{km} f_m\}$$

- Updating the dual variables

$$q_{km} \leftarrow [q_{km} + \alpha(s_{up(k,m),m} - s_{km})]_+$$

Thanks!

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