Modeling Random Multiple Access

Моделирование случайного множественного доступа

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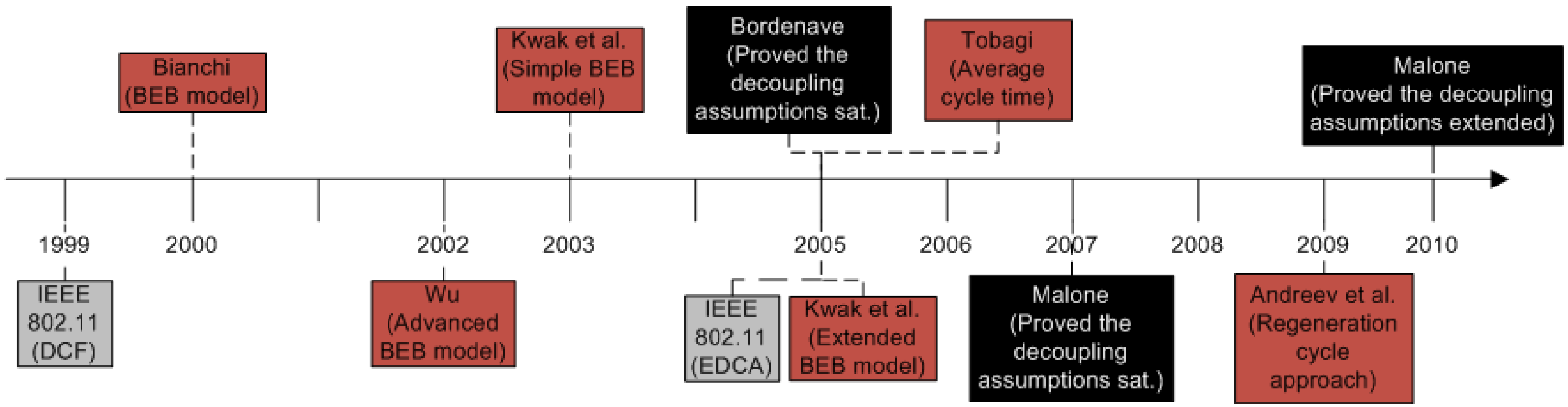
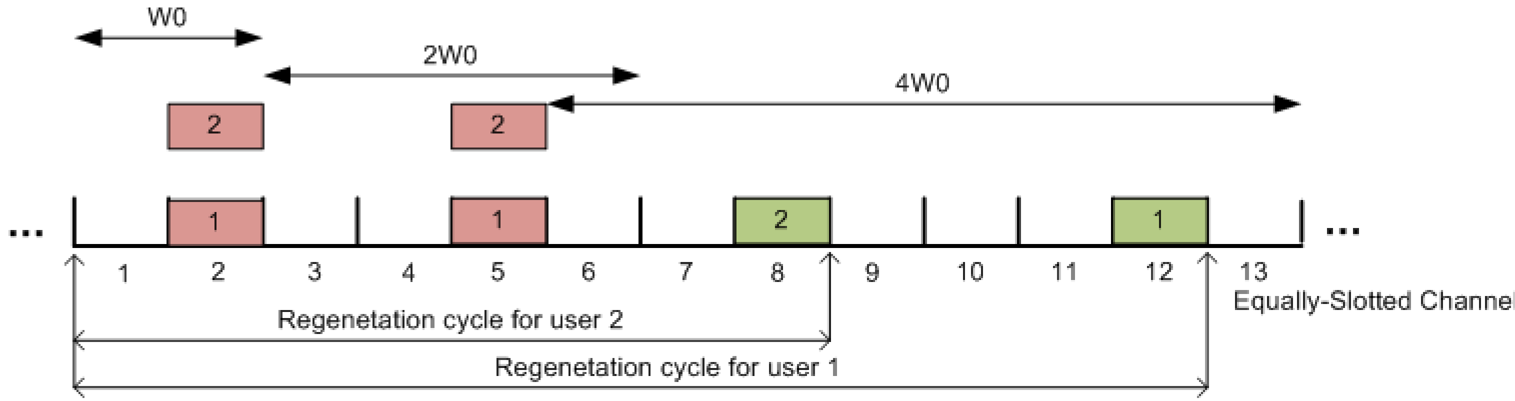
Background – Homogeneity



- IEEE 802.11 **standards**
- **Binary Exponential Backoff** analytical **models** (1-D, 2-D, Average cycle time, Regeneration cycle approach) [Bianchi 2000, Kwak and Miller 2003, Tobagi 2005]
- **The main model assumptions** verified for saturated traffic [Bordenave 2005, Malone 2010]

Binary Exponential Backoff (BEB)



- Model from Kwak et al.
- **Lossless** system (no packet retry limit)
- Using the **regeneration cycle approach**

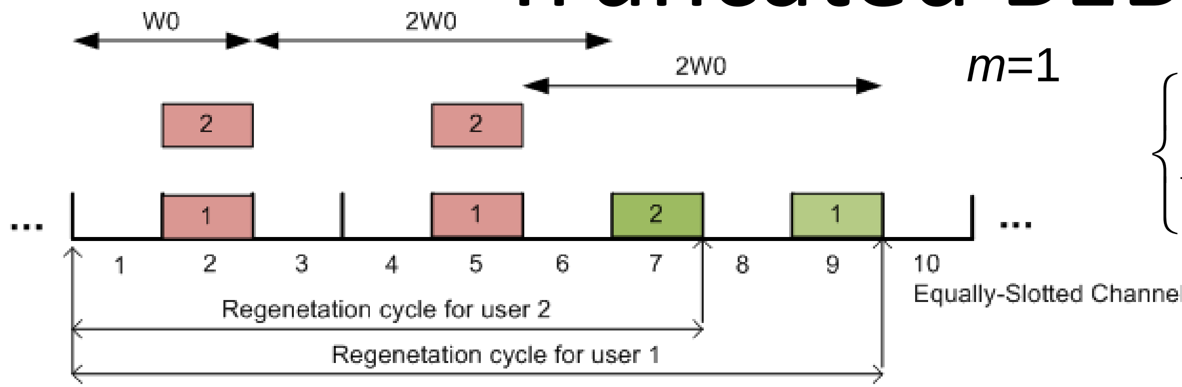
$$p_t = \frac{E[B]}{E[D]} = \frac{2(1-2p_c)}{W_0(1-p_c)+(1-2p_c)}$$

E[B]=Average nº of transmission attempts in a cycle
E[D]=Average number of conteding slots in a cycle

- For a network with *M* users, the **conditional collision probability** is:

$$\mathrm{p}_c = 1-\left(1-p_t\right)^{M-1}$$

Truncated BEB



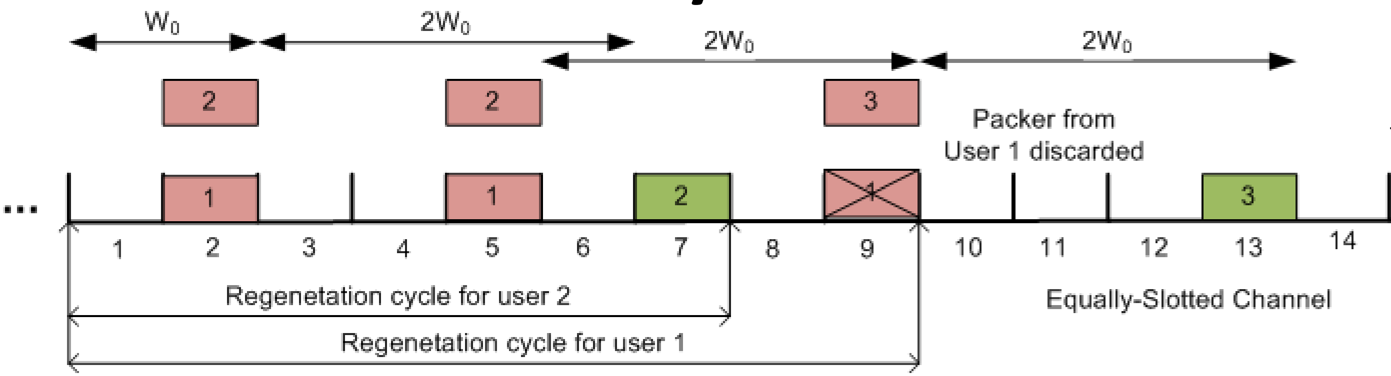
m=1

$$\begin{cases} W_i = 2^i W_0, & \text{if } 0 < i < m \\ W_i = 2^m W_0, & \text{if } i \geq m \end{cases}$$

- Bianchi's Model
- **Fairness** improvement
- **Lossless** system
- Finite number of BEB **stages** *m*
- Using the regeneration cycle approach:

$$p_t = \frac{2(1-2p_c)}{(1-2p_c)(W_0+1)+p_c W_0\left(1-(2p_c)^m\right)}$$

Lossy Truncated BEB



$$\begin{cases} W_i = 2^i W_0, & \text{if } 0 < i < m \\ W_i = 2^m W_0, & \text{if } m < i \le k \end{cases}$$

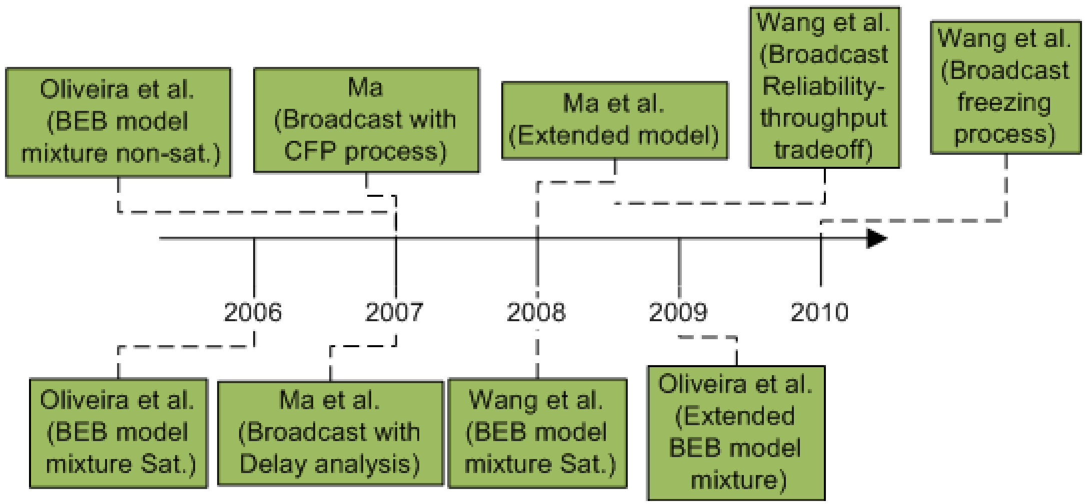
$k = 3$

$m = 1$

- Our previous work on IEEE 802.16
- **Finite** number of BEB **stages** *m*
- **Fixed** number of unicast packet **transmissions attempts** *k*
- There are 2 expressions for the transmission probability:

$$p_t = \begin{cases} \dfrac{2(1-2p_c)(1-p_c^k)}{W_0(1-p_c)\left(1-(2p_c)^k\right)+(1-2p_c)(1-p_c^k)}, k \le m+1 \\ \dfrac{2(1-2p_c)(1-p_c^k)}{(1-2p_c)\left(W_0(1-2^m p_c^k)+(1-p_c^k)\right)+p_c^k W_0\left(1-(2p_c)^m\right)}, k > m+1 \end{cases}$$

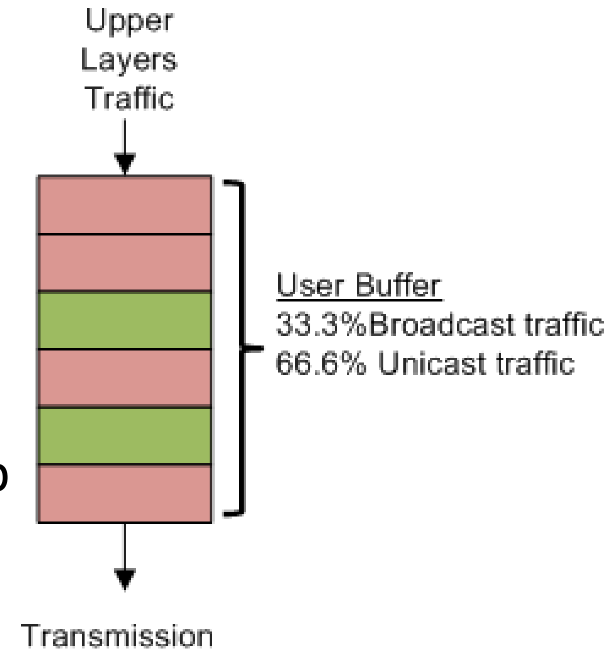
Background – Unicast vs. Broadcast Traffic



- Broadcast **saturation** traffic conditions models [Ma, Wang]
- Unicast and Broadcast **saturation** traffic conditions models [Oliveira, Wang]
- Unicast and Broadcast **non-saturation** traffic conditions models [Oliveira, Wang]

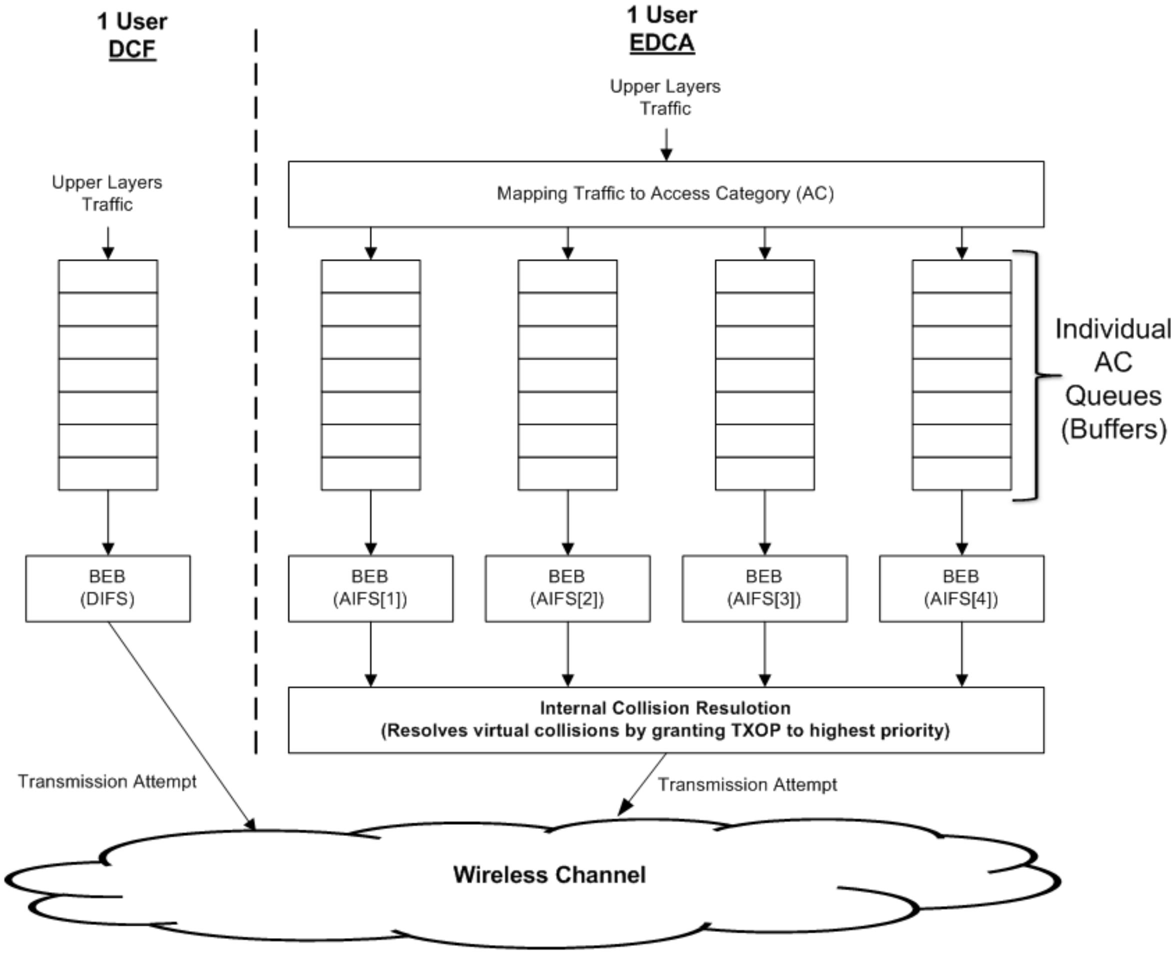
Proposed Model

- **Lossy** system
- **Extends** our earlier work
- **Broadcast** packet generation p_b
- **Unicast** packet generation p_u=1- p_b
- **Finite** *m* and *k*
- The **novel** 2 expressions for p_t are:



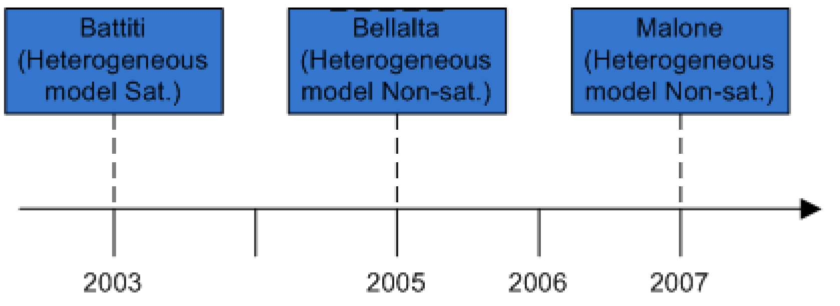
$$p_t = \begin{cases} \dfrac{2(1-2p_c)\left[\left(1-p_c^k\right)p_u + (1-p_c)p_b\right]}{\left(W_0(1-p_c)\left(1-(2p_c)^k\right)+(1-2p_c)\left(1-p_c^k\right)\right)p_u + (W_0+1)(1-2p_c)(1-p_c)p_b}, & k \le m+1 \\ \dfrac{2(1-2p_c)\left[\left(1-p_c^k\right)p_u + (1-p_c)p_b\right]}{\left((1-2p_c)\left(W_0\left(1-2^m p_c^k\right)+\left(1-p_c^k\right)\right)+p_c^k W_0\left(1-(2p_c)^m\right)\right)p_u + (W_0+1)(1-2p_c)(1-p_c)p_b}, & k > m+1 \end{cases}$$

Enhanced Distributed Channel Access (EDCA)



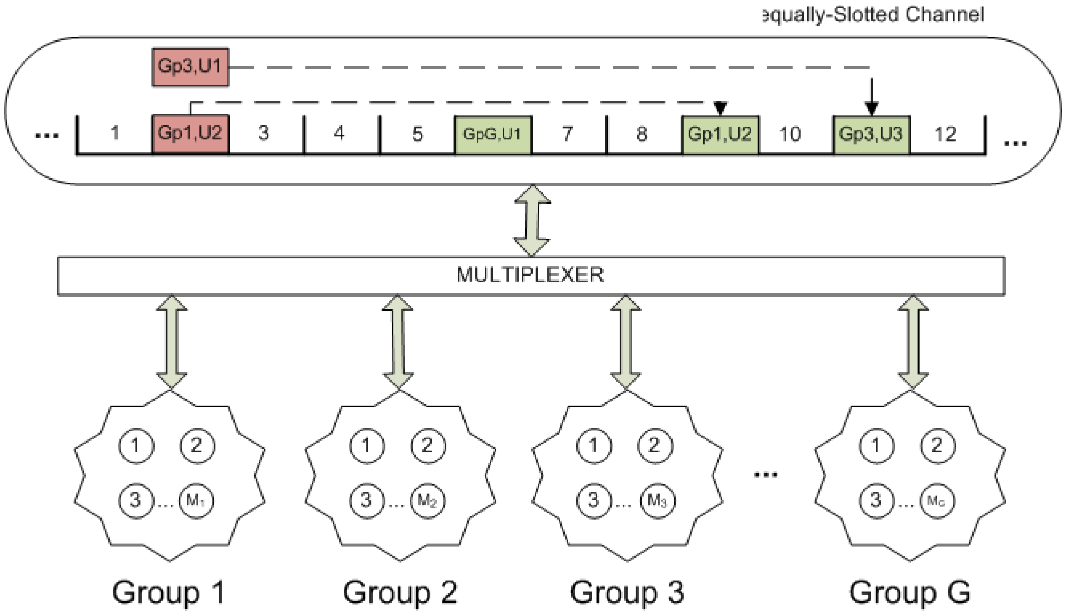
- **Quality of Service** extensions
- Different channel access probabilities for different **traffic classes**
- Internal **collision resolution**

Background – Heterogeneity



- **Heterogeneity** models for Ad-Hoc networks
- **Only** accounts for **unicast** traffic
- **Saturation** traffic conditions models [Bellalta 2003, Malone 2007]
- **Non-saturation** traffic conditions models [Bellalta 2005, Malone 2007]

Proposed Model – Heterogeneity

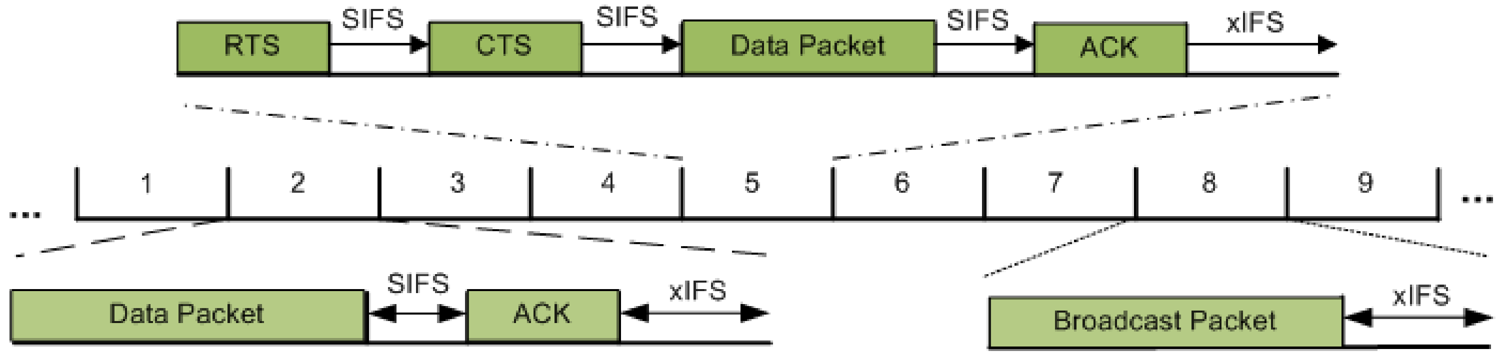


- **Heterogeneous** network
- *G* diverse **groups** of users
- Packet retry limit
- Co-existence of traffic
- Equally-slotted system
- **Backward compatibility** with previous models

For each group *j*, the p_c and p_t are given by: $p_c^{(j)} = 1-\left(1-p_t^{(j)}\right)^{n_j-1} \prod_{i=1;i\neq j}^{G} \left(1-p_t^{(i)}\right)^{n_i}$

$$p_t^{(j)} = \begin{cases} \dfrac{2(1-2p_c)\left[\left(1-p_c^k\right)p_u+(1-p_c)p_b\right]}{\left(W_0(1-p_c)\left(1-(2p_c)^k\right)+(1-2p_c)\left(1-p_c^k\right)\right)p_u+(W_0+1)(1-2p_c)(1-p_c)p_b}, & k\le m+1 \\ \dfrac{2(1-2p_c)\left[\left(1-p_c^k\right)p_u+(1-p_c)p_b\right]}{\left((1-2p_c)\left(W_0\left(1-2^m p_c^k\right)+\left(1-p_c^k\right)\right)+p_c^k W_0\left(1-(2p_c)^m\right)\right)p_u+(W_0+1)(1-2p_c)(1-p_c)p_b}, & k>m+1 \end{cases}$$

Unequally-Slotted System



- Each slot is **rescaled** according to the type of packet transmitted (IEEE 802.11x)
- Unicast packets
  - Basic Access
  - RTS/CTS
- Broadcast packets
- **Throughput** expression (**estimation**):

$$S = \frac{\sum_{j=1}^{G}\left[P_{S,j}E[P]\right]}{P_{idle}T_{idle} + \sum_{j=1}^{G}P_{S,j}T_{S} + P_{c}T_{c}}$$

$P_{S,J}$, **P_{idle}** and **P_c** – System-wide probabilities

T_S, **T_{idle}** and **T_c** – Slot timings

Summary

- Simplified **saturation** models of ALOHA and BEB
  - Account for **limited** unicast packet **transmission attempts**
  - Take into account both **unicast** and **broadcast** traffic
  - Allow joint access of different **groups** of users
  - Enable **throughput** estimation

- Open issues
  - Extending to non-saturated traffic conditions
  - Attacking bursty traffic
  - Actual throughput and protocol overhead with LAYERING