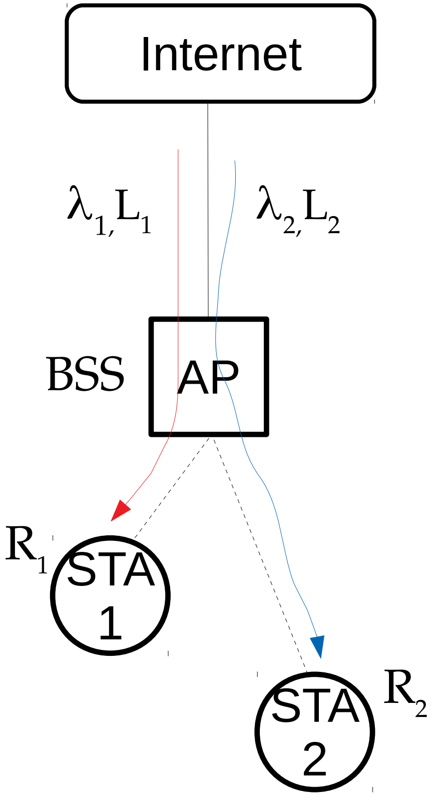
Network Engineering
Downlink WIFI Model

Boris Bellalta
boris.bellalta@upf.edu

Downlink WiFi Model

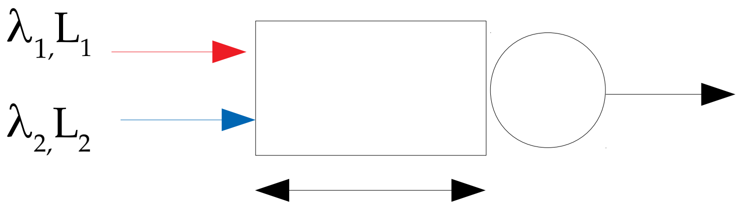
- Only Donwlink traffic $\rightarrow$ the AP is the only node transmitting
  - Uplink traffic is negligible [Assumption]
- We model a WIFI AP as if it was a M/M/1/K queue
  - Packet arrivals for all traffic flows (directed to the stations) follow a Poisson process [Assumption]
  - The expected service time for the aggregate traffic is exponentially distributed [Assumption]

A WLAN at home (1 AP)

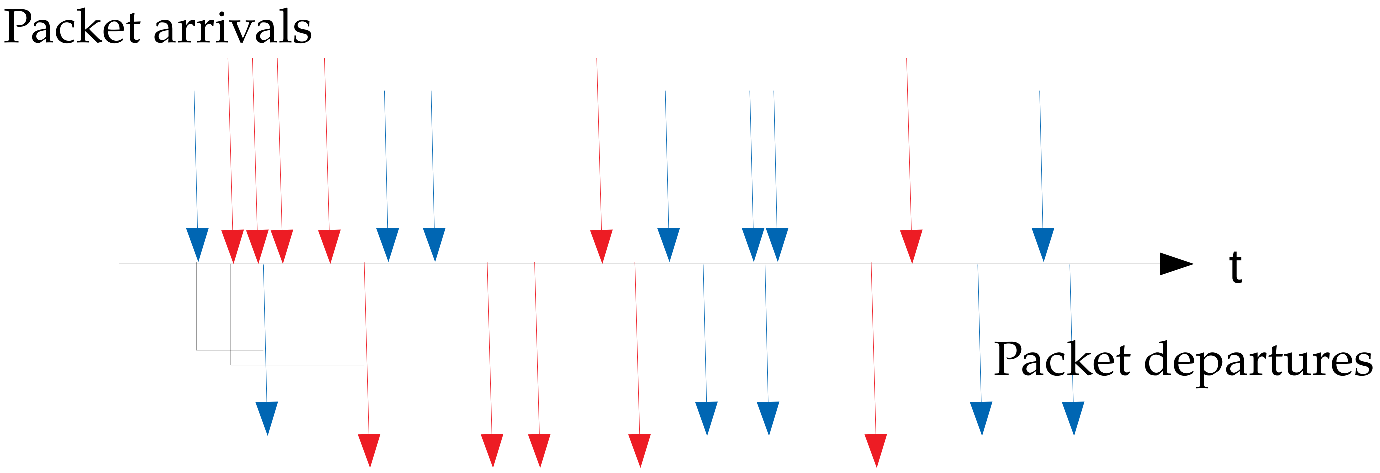


BSS: Basic Service Set

N flows (as active stations)



Q = buffer capacity of the AP



Downlink WiFi Model

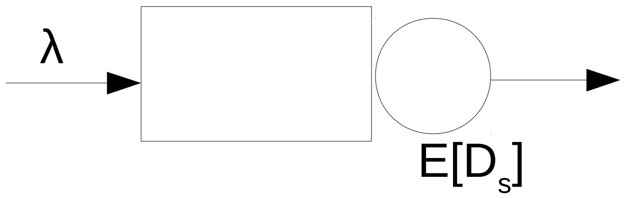
1. The packet arrival rate per flow is $\{\lambda_1,\ \lambda_2,\ \ldots\ ,\lambda_N\}$.
2. The aggregate packet arrival rate is $\lambda = \sum_{n=1}^{N} \lambda_n$
3. The packet transmission time per flow is given by

$$\{T_1(R_1, L_1),\ T_2(R_2, L_2),\ \ldots\ ,T_N(R_N, L_N)\},$$

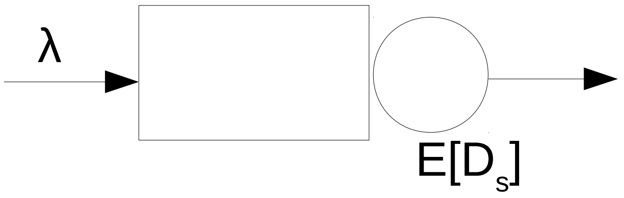
   where R_n is the transmission rate experienced by station n, and L_n is the size (average) of the packets directed to station n.

4. The expected packet transmission time of the system is given by:

$$E[D_s] = \sum_{n=1}^{N} \frac{\lambda_n}{\lambda} T_n(R_n, L_n)$$



Downlink WiFi Model



5. Normalized traffic load per flow: $a_n = \lambda_n T_n(R_n, L_n)$

6. Normalized aggregate traffic load: $a = \lambda E[D_s] = \sum_{n=1}^{N} a_n$

7. We obtain the stationary probability distribution: $\pi_n = \frac{(1-a)a^n}{1-a^{K+1}}, \ \forall\ n$, where $K = Q + 1$ is the AP packets storage capacity (including the packet in transmission).

8. The AP utilization is given by $\rho = 1 - \pi_0 = a(1 - P_b)$

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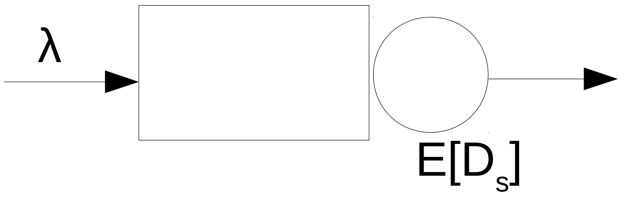

9. The packet blocking probability is $P_b = \pi_K$

10. The expected AP delay for flow n is $E[D]_n = T_n(R_n, L_n) + E[D_q]$. Note that the term $E[D_q]$ is the same for all flows, as the time a packet waits in the buffer depends on the packets that have arrived before it (and are still waiting).

11. The expected AP delay is given by $E[D] = \sum_{n=1}^{N} \frac{\lambda_n}{\lambda} E[D]_n = \frac{E[N]}{\lambda(1-P_b)}$

12. The expected AP buffer delay is given by $E[D_q] = \frac{E[N_q]}{\lambda(1-P_b)}$

Example

```
Load (Mbps)
     0.5000
     2.0000
     1.0000
     2.0000
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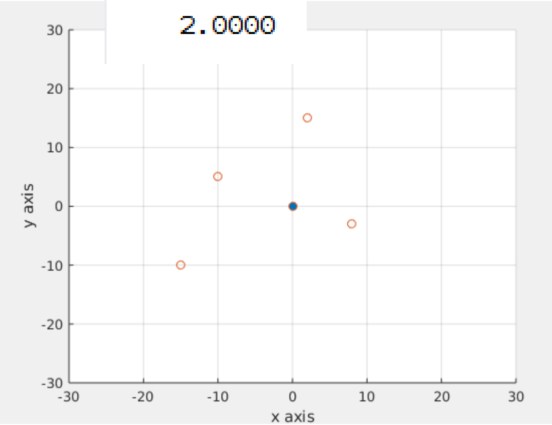


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Distance AP-station (meters), Path-loss (dBs), Received Power (dBms), and Transmission Rate (Mbps)
   15.1327   77.4939  -57.4939   10.0000
   11.1803   56.0273  -36.0273   20.0000
   18.0278   94.2463  -74.2463    5.0000
    8.5440   42.8604  -22.8604   20.0000

----------------------------------------------------------------------------------------------
Transmission Duration (miliseconds)
    1.0537    0.4361    2.6889    0.3361

Expected service time (miliseconds) | Traffic Load (Erlangs)
    0.5129    0.8441

Blocking Prob | Empty Prob | AP Utilization
    0.0278    0.1794    0.8206

AP and buffer occupancy (packets) | Expected system and Waiting delay (seconds)
    3.6078    2.7872    0.0023    0.0017

-----------------------------------------------------------------------
Expected Individual System Delay (seconds)
    0.0028    0.0022    0.0044    0.0021

Load (Mbps) | Throughput (Mbps)
    0.5000    0.4861
    2.0000    1.9444
    1.0000    0.9722
    2.0000    1.9444
```