Roommate Wi-Fi Sharing: Balancing Router Capacity and User Experience

Program: Telecommunications and Information Security (MEng)

Course: Design and Analysis of Communication Networks

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• ABSTRACT:

This study aims to estimate the maximum number of roommates who can share an Internet subscription using an IEEE 802.11a/b/g/n wireless router providing a satisfactory Internet experience for every user. By modelling user Internet activity with Markov chains – Queuing Analysis and considering the upstream and downstream capacity limits alongside the router's capacity, we develop an analytical approach to determine the optimal number of users. The results provide valuable insights for network planning in residential settings.

• SYSTEM MODEL

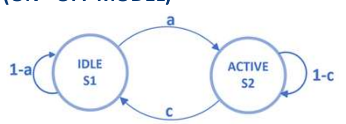
❖ Device Compatibility

Wi-Fi standards	Frequency	Max throughput
IEEE 802.11.b	2.4 Ghz.	11 Mbps
IEEE 802.11.a	5 Ghz.	54 Mbps
IEEE 802.11.g	2.4 Ghz.	54 Mbps
IEEE 802.11.n	2.4 GHz and/or 5 GHz (dual-band capable)	Up to 300 Mbps (theoretical)*

Table. IEEE Wi-Fi standards

- ❖ Maximum Real Throughput for IEEE802.11n: 300Mbps * 80% = **240 Mbps.**
- ❖ Internet subscription. Symmetric Upload and Download = **240Mbps.**
- ❖ Bandwidth per User Requirement – For General Usage = **At least 5Mbps.**
- ❖ Router Buffer Size – Average buffer size for consumer-grade routers = **64 packets.**
- ❖ Internet User Activity Patterns (General Internet Usage) = **25%**

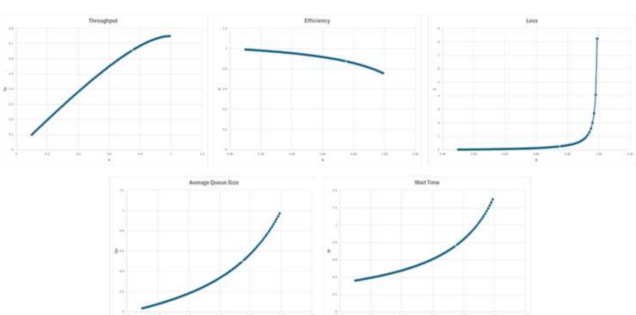
MARKOV CHAIN – (ON - OFF MODEL)



MARKOV CHAIN RESULTS

- **State Transition Matrix** $\begin{vmatrix} 1-a & c \\ a & 1-c \end{vmatrix}$
- **Steady State Probability** $S_1 * a = S_2 * c$ $\quad S_2 = S_1 * \frac{a}{c}$ $\quad S_1 + S_2 = 1$

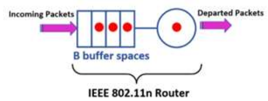
$$S_1 = \left(\frac{c}{c+a}\right) \qquad S_2 = \left(\frac{a}{c+a}\right)$$



• PERFORMANCE ANALYSIS - M/M/1/B QUEUE THEORY

❖**System Parameters**

- Buffer Size: 64 packets.



- Packet Arrival Rate per User:

$$\text{Arrival rate per active user} = \frac{\text{Minimum Bandwidth per User}}{\text{Average Packet Size}}$$

$$\text{Arrival rate per active user} = \frac{5 \times 10^6 \text{ bps}}{(1500 \text{ bytes} * 8 \text{ bits})} = 416.7 \text{ pps (packet per second)}$$

- Total Arrival Rate for N Users:

$$\text{Total Arrival Rate} = \text{N users} * \text{a} * \text{Arrival rate per active user}$$
$$\text{Total Arrival Rate} = \text{N users} * 0.25 * 416.7 = 104.17 * N \text{ pps}$$

- Router's Capacity:

$$\text{Router's Capacity} = \frac{\text{Max Real Throughput for IEEE802.11n.}}{(1500 \text{ bytes} * 8 \text{ bits})}$$

$$\text{Router's Capacity} = = \frac{240 \times 10^6 \text{ bps}}{12000 \text{ bits}} = 20.000 \text{ pps}$$

- System's capacity **ρ** (distribution index):

$$\rho = \frac{\text{Total Arrival Rate for N users}}{\text{Router's Capacity}} = \frac{104.17 * N \text{ pps}}{20.000 \text{ pps}} = 0.005208 * N$$

- State probability distribution

$$Si = \frac{(1-\rho)\rho^i}{1-\rho^{B+1}} \quad 0 \le i \le B$$

- State probability of the system being in the last state S_B

$$S_B = \frac{\rho^B * (1-\rho)}{1-\rho^{B+1}} \qquad S_B = \text{Blocking Probability} = \frac{\rho^B * (1-\rho)}{1-\rho^{B+1}}$$

- Throughput (Th) Th = Total Arrival Rate * (1- S_B) (packets/sec)
- Average Queue length Qa. $Qa = W * Th$
- Average Waiting Time W. $W = \frac{Qa}{Th}$

• PERFORMANCE RESULT – Calculating N users based on QoS constraints.

❖Calculation approach.

- Acceptable Blocking Probability SB.

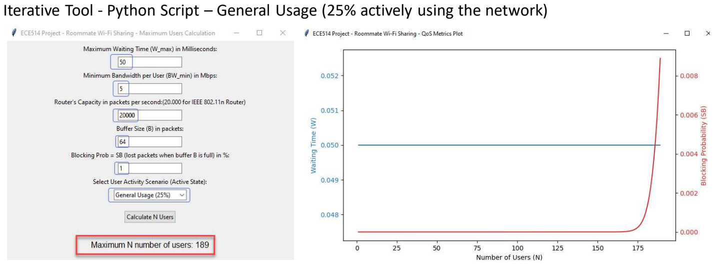
$$S_B = \text{Blocking Probability} = \frac{\rho^B * (1-\rho)}{1-\rho^{B+1}} < 0.01$$

- Maximum Average Packet Delay W.

$$W = \frac{Qa}{Th} \le 0.05 \text{ seconds}$$

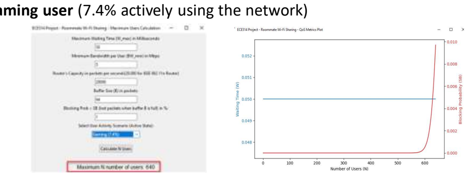
ITERATIVE METHOD: Evaluating different N values to fit performance metrics.

- Iterative Tool - Python Script – General Usage (25% actively using the network)

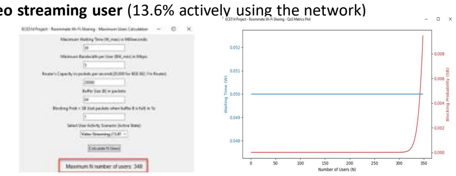


• PERFORMANCE EVALUATION – COMMON ACTIVITY PATTERNS

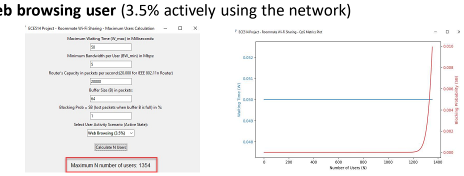
❖**Gaming user** (7.4% actively using the network)



❖**Video streaming user** (13.6% actively using the network)



❖**Web browsing user** (3.5% actively using the network)



• CONCLUSIONS

- ❖ Bursty traffic patterns, like in web browsing, create low average demand, enabling networks to support significantly more users while maintaining QoS.
- ❖ User Behavior Determines Capacity: Low-activity tasks like web browsing support more users, while high-demand tasks like video streaming reduce capacity.
- ❖ QoS Ensures Stability: Blocking probability and waiting time (delay) constraints maintain user experience and network reliability.
- ❖ Iterative Analysis: Iterative tools like Python precisely identify the maximum number of users (N).
- ❖ Scalable Methodology: The M/M/1/B model and realistic parameters apply broadly to analyze various network scenarios.

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