Bandwidth Aggregation for Real-time Application in Heterogeneous Wireless Networks

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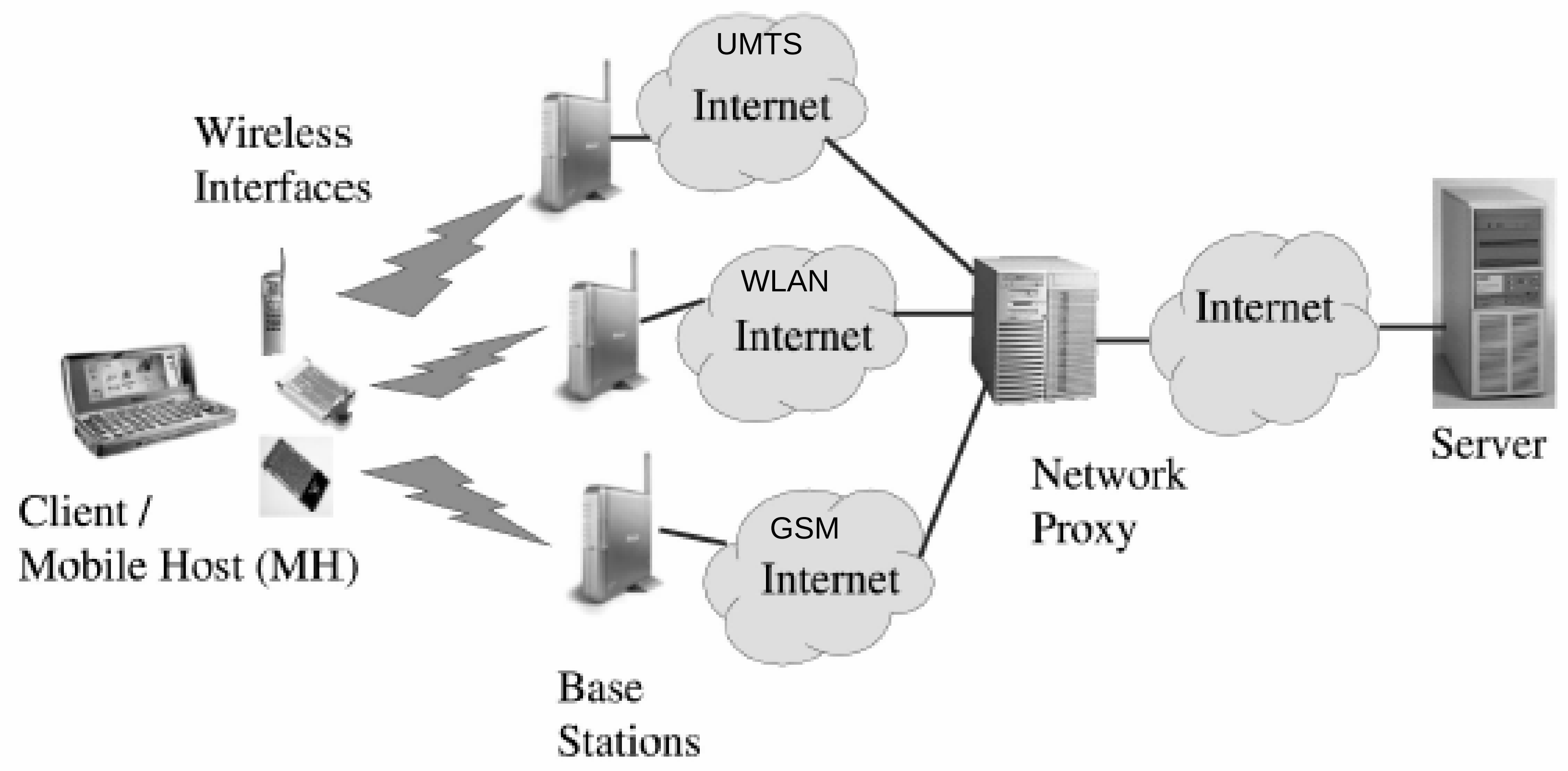
Outline

- Introduction
- Architecture
- Scheduling algorithm : Earliest Delivery Path First (EDPF)
- Properties of EDPF
- Evaluation
- Conclusion

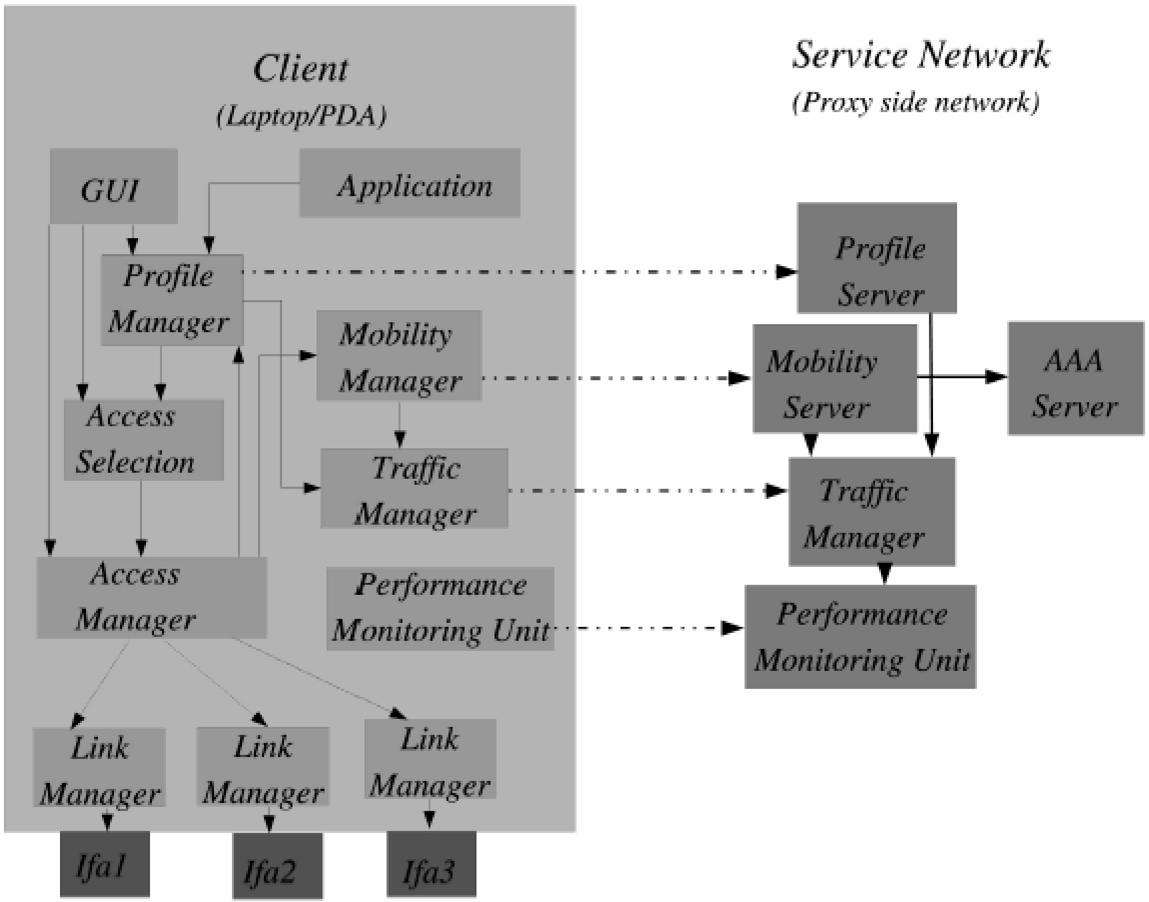
Introduction

- A variety of wireless interfaces are available for today's mobile user to access Internet content.
- When coverage areas of these different technologies overlap, a terminal equipped with multiple interfaces can use them simultaneously to improve the performance of its applications.
- An important aspect of the architecture when providing BAG services for real-time applications is the scheduling algorithm that partitions the traffic onto different interfaces such that the QoS requirements of the application are met.
  - Earliest Delivery Path First (EDPF)

Architecture



Architecture



- **Profile Manager/Server** : interfaces, scheduling, additional functionality
- **Access Manager/Selection**: selects interface based on the profile or scheduling algorithm
- **Mobility Manager/Server** : register, address acquire
- **Traffic Manager** : scheduling algorithm

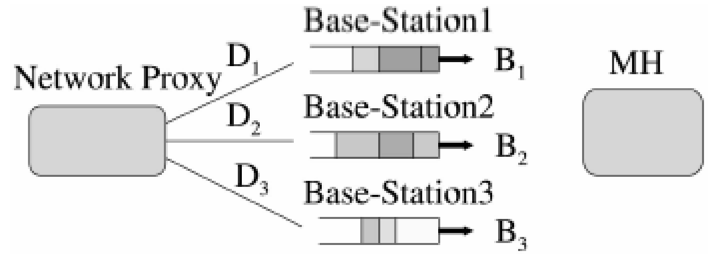
Earliest Delivery Path First (EDPF)

- The overall idea behind EDPF

1. Take into consideration the overall path characteristics between the proxy and the MH—delay, as well as the wireless bandwidth.
2. Schedule packets on the path which will deliver the packet at the earliest to the MH.

Earliest Delivery Path First (EDPF)

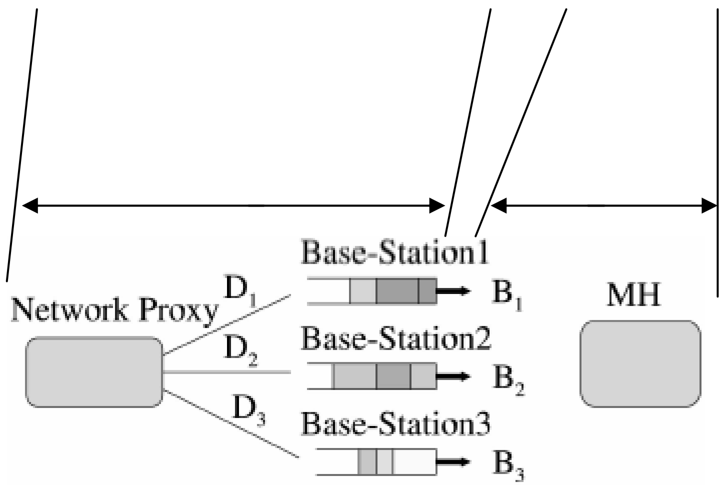
$$d_i^l = MAX(a_i + D_l, A_l) + L_i / B_l$$



- D_l : the one-way wireline delay associated with the path (between the proxy and Base Station)
- B_l : the bandwidth negotiated at the BS
- A_l : the time of the wireless channel becomes available for the next transmission at the BS
- a_i : the arrival instance of the ith packet (at the proxy)
- L_i : the size of the packet
- This packet when scheduled on path l would arrive at the MH at d_i^l .

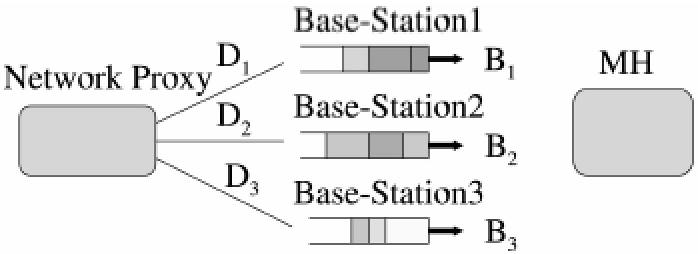
Earliest Delivery Path First (EDPF)

$$d_i^l = MAX(a_i + D_l, A_l) + L_i / B_l$$



- The first component computes the time at which transmission can begin at the BS.
- The second component computes the packet transmission time.

Earliest Delivery Path First (EDPF)



- Example

$$d_i^l = MAX(a_i + D_l, A_l) + L_i / B_l$$

  - L=100bits, D1=3s, A1=4s, B1=20bps
  - D2=5s, A2=2s, B2=10bps
  - d1=max(3,4)+100/20=4+5=9
  - d2=max(5,2)+100/10=5+10=15
  - The delivery path is path1.

Properties of EDPF

- When packets are of constant size, it is easy to see that with EDPF, they will arrive in order at the client.
  - Consider two packets {i,j : j>i}
  - Packet j may arrive before i only if it were scheduled on a different link.
  - the link on which j was transmitted delivers packets the earliest, EDPF when scheduling i would have picked that link for its transmission.
  - Thus, packets will always arrive in order.

Properties of EDPF

- When packets are of variable size, it is important that the scheduling algorithm distribute the bits across the links properly.
- we can say the algorithm achieves good bandwidth aggregation if the maximum difference between the normalized bits allocated to any two pairs of links m; n is at most a constant.
- The constant should not be a function of the number of packets.

Properties of EDPF

- For EDPF, given P packets to transmit, the maximum difference between the normalized bits allocated to any two pairs of links m; n is upper bounded by Lmax.

$$max_{m,n}\left|\frac{Sent_m}{w_m}-\frac{Sent_n}{w_n}\right| \leq L_{max}$$

  - Lmax : the maximum packet size
  - Sent : the total number of bits sent on the link
  - W : the weight of the link ($W=B/B_{min}$)

Properties of EDPF

$$\left|\frac{Sent_m}{w_m} - \frac{Sent_n}{w_n}\right| = \left|\frac{T_m(t) * B_m}{w_m} - \frac{T_n(t) * B_n}{w_n}\right|$$ =[Tm(t)-Tn(t)]*Bmin

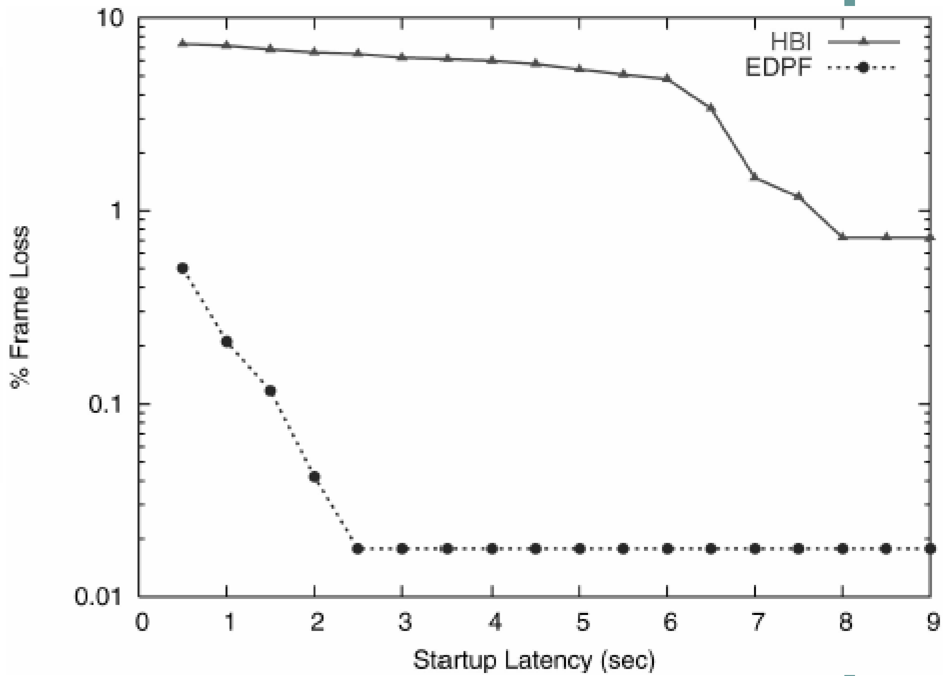
- T(t) is in essence the time at which a packet arriving at time t can begin transmission on link.
- T(t) would essentially indicate the overall time for which the link was used for transmission.
- Therefore, T(t) * B would be the total number of bits sent on the link.
- B/W=Bmin (∵ W=B/Bmin)
- The difference between the Ts cannot exceed Lmax/Bmin.

Evaluation

- Streaming video

Buffering Time (in Seconds) for Continuous Playback

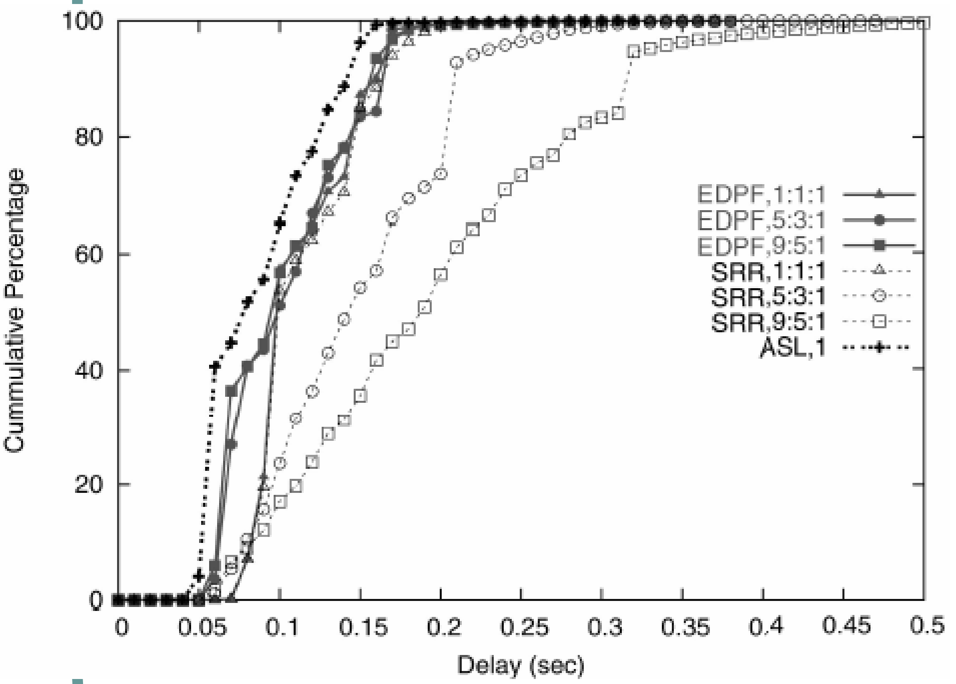
Algo./ Video	Lecture ⟨58, 690⟩	Star Trek ⟨69, 1200⟩	Star Wars ⟨53, 940⟩	Susi & Strolch ⟨79, 1300⟩
EDPF	2.3	3.1	2.9	4.6
HBI	7.9	8	8.3	8.6

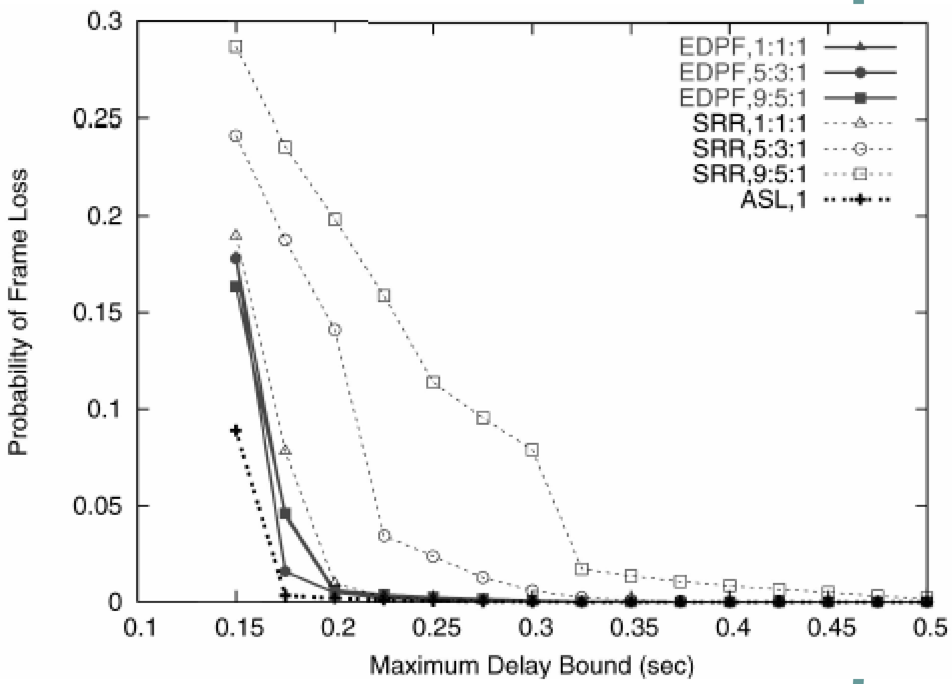


- HBI (Highest Bandwidth Interface)

Evaluation

- Interactive video

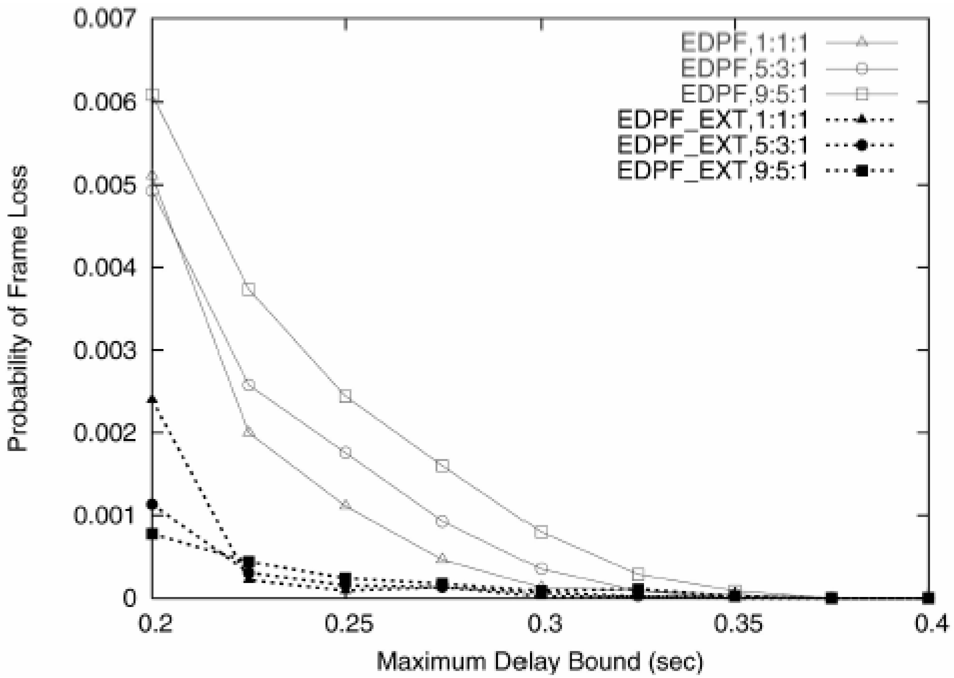




- SRR (Surplus Round Robin)

Evaluation

- If the MH provides EDPF with additional information such as maximum tolerable delay, EDPF can drop packets that are unlikely to meet their delay constraints.



Conclusions

- The authors use multiple interfaces simultaneous with EDPF.
- When packets are of constant size, they will arrive in order at the client.
- When packets are of variable size, the maximum difference between the normalized bits allocated to any two pairs of links m; n is upper bounded by a constant (Lmax).