Resource Allocation with Differentiation for Wireless Video Transmission

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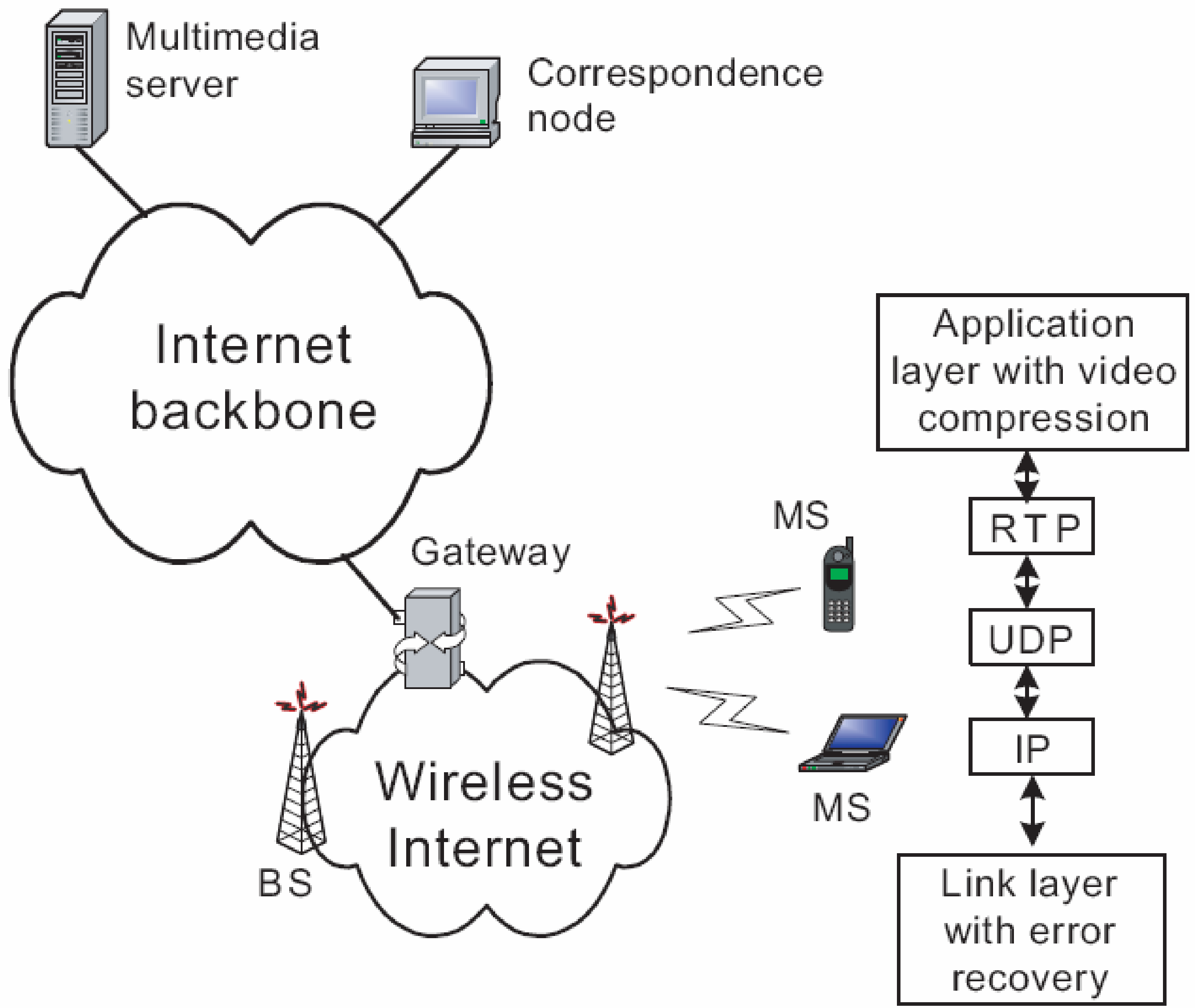
Introduction

- The next generation wireless networks need to support video traffic.
- A major challenge in video services over wireless networks is quality of service (QoS) provisioning.
- Service differentiation is a good approach for QoS provisioning to video traffic.
- a cross-layer protocol stack architecture for wireless video transmission with service differentiation is proposed in this paper.

System Architecture

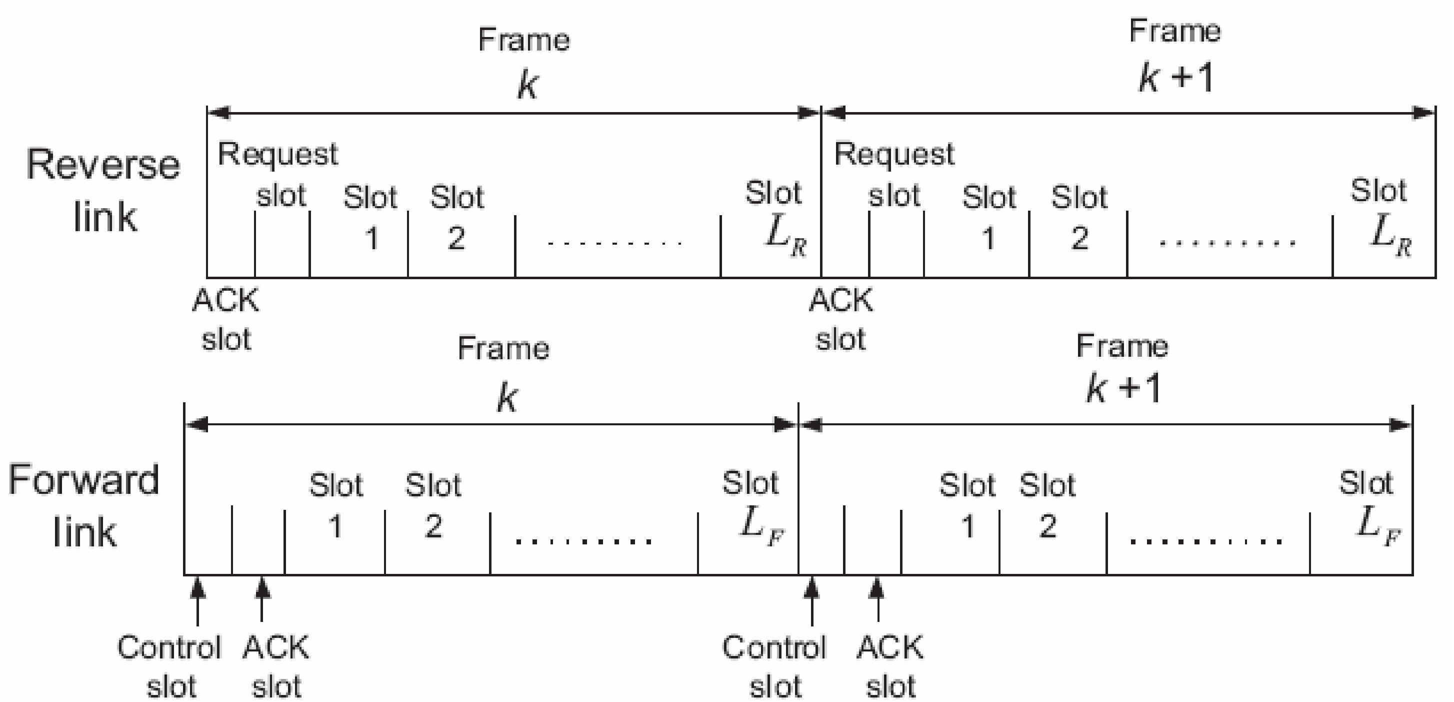


Video Compression Information

- In layered coding, a raw video sequence is coded into multiple layers:
  - The base layer contains the most important features of the video and can be independently decoded to provide coarse visual quality.
  - The enhancement layers contain information to further improve the achieved video quality when decoded together with the base layer.
- In MPEG-4
  - I-frame: intra-coded
  - P-frame: forward prediction
  - B-frame: bidirectional prediction

Hybrid TD/CDMA Structure at the Link Layer

- The time frames of the forward and reverse links operating in frequency division duplexing (FDD) mode.
- Time is partitioned into fixed length frames in the structure.



Hybrid TD/CDMA Structure at the Link Layer

- Each compressed (base or enhancement) layer of a video frame is segmented into a batch of link layer packets (called LL packets).
- The MS creates a transmission queue for each batch of the video frame, assigns a timer with a timeout value to each batch.
  - If an LL packet is transmitted successfully, an ACK will be received before any packet slot of next LL frame, and the packet will be removed from the transmission queue at the MS side.
  - Otherwise, this LL packet will remain in the queue until a successful retransmission or a timeout event of the batch timer.

Link-Layer Resource Allocation

- Because of the bursty nature of multimedia traffic and the limited radio resources, a flexible resource allocation scheme which can efficiently accommodate multimedia traffic flows at the link layer is required.
- The basic principle of GPS is to assign a fixed weight to each session, and allocate bandwidth for all the sessions according to their weights and traffic load.
- If GPS is used, a large weight should be assigned to a video session in order to guarantee the peak rate.
  - dynamic weights in GPS

Dynamic-Weight GPS

- In DWGPS, a "session" is defined as an active batch in the transmission queue.
- A session is assigned a DWGPS weight

$$\text{The weight of batch} \cdot \frac{\text{The size of batch}}{\text{The timer of batch}}$$

(The weight for class) (The service capacity required by batch)

Ex:	3	20/2
	1	35/1

DWGPS Scheduling Procedure

- Credit Value

The estimated number of LL packets to be scheduled from batch	−	The actually scheduled LL packet number from batch

- Remaining Service Capacity

Service capacity	−	The actually scheduled LL packet number from all batches

DWGPS Scheduling Procedure

- Step 1
  - Collect the remaining credit values of the batches from last frame.
  - Delete the batches whose LL packets are all transmitted successfully or whose timer values are 0.

DWGPS Scheduling Procedure

- Step 2
  - Determine the estimated number of LL packets to be scheduled from batch.

$$\frac{\text{The weight of batch}}{\text{The sum of the weights of all batches}} \cdot \text{Service capacity}$$

  - Add the credit value from the same batch to the estimated number of LL packets to be scheduled.
  - According to the weight of the batch, add a portion of the sum of the credit value to the estimated number of LL packets to be scheduled

$$\frac{\text{The weight of batch}}{\text{The sum of the weights of all batches}} \cdot \text{The sum of credit value}$$

  - Set the credit value to 0.

DWGPS Scheduling Procedure

- Step 3
  - Determine The actually scheduled LL packet number from batch.

$$\min\left\{ \text{The remaining size of batch},\ \left\lfloor \text{the estimated number of LL packets to be scheduled from batch} \right\rfloor \right\}$$

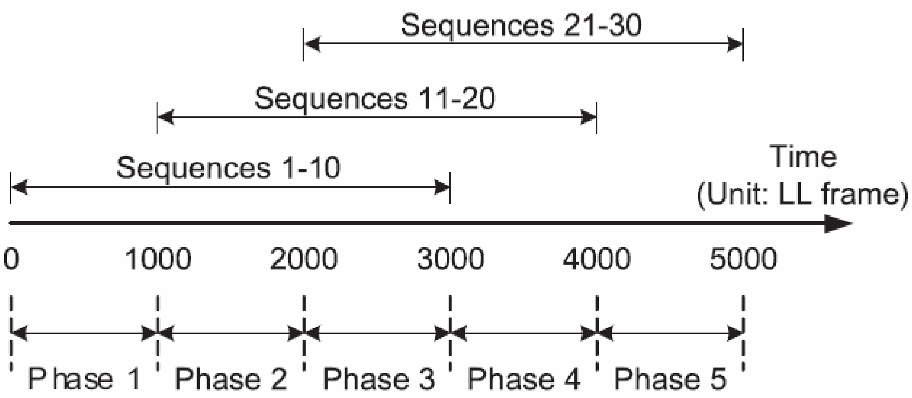
  - Determine the credit value for each batch

DWGPS Scheduling Procedure

- Step 4
  - Determine the remaining service capacity
    - If the value of the remaining service capacity is positive
      - Find the batch with biggest credit value
      - Assign the remaining capacity to the batch
      - Reduce the credit value and the remaining service capacity value of the batch
    - If the value of the remaining service capacity is negative
      - Find the batch with smallest credit value
      - Take from the service capacity of the batch
      - add the credit value and the remaining service capacity value of the batch
    - If the value of the remaining service capacity equals 0
      - Finish the scheduling procedure for this LL frame

Performance Evaluation

- The traffic load phases in the simulations



- Compare with MRED(Multi-level Random Early Detection) and priority scheduling
- The MRED parameters (min_i, max_i, P_{max_i}), $i \in \{IB, PB, E\}$, are ($0.6Q$, $0.8Q$, 0.025), ($0.4Q$, $0.6Q$, 0.05), and ($0.2Q$, $0.4Q$, 0.1) for IB, PB, and E batch classes, respectively.

PARAMETERS USED IN SIMULATIONS.

Parameter	Value
Number of video sequences	30
Batch class types	IB, PB, E
Importance weights in LL frame k	$w_{IB}(k) \geq w_{PB}(k) \geq w_E(k)$
LL frame duration (T_f)	10 ms
Number of packet slots per frame in the reverse link (L_R)	8
Wireless delay bound D	15 LL frames
Payload bit number in each LL packet (S_l)	192
Link layer transmission success probability (P_s)	0.9
Traffic load phase	1, 2, 3, 4, 5
Total average arrival rate (in kbps) of IB class in phase 1 - 5	220, 443, 655, 351, 171
Total average arrival rate (in kbps) of PB class in phase 1 - 5	93, 233, 397, 295, 192
Total average arrival rate (in kbps) of E class in phase 1 - 5	653, 1335, 1999, 1345, 721
Capacity value $C(k)$ for LL frame k in phase 1 - 5	60, 60, 48, 32, 36
Capacity (in kbps) for phase 1 - 5	1037, 1037, 829, 553, 622
The same velocity (kilometer/hour) for all MSs	0.5, 15
Doppler frequency shift (f_D) at carrier frequency 2 GHz	0.9 Hz, 27.8 Hz
Channel coherence time	1080 ms, 36 ms
Normalized fading rate $(f_D T_f)$	0.009 (slow fading), 0.278 (fast fading)

LL PACKET LOSS RATES OF IB, PB, AND E CLASSES FOR PHASE 1-5 FOR MRED[11]/DWGPS/PRIORITY SCHEDULING

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
$P_e(IB)$ (%)	0/0/0	7.9/0.7/0	22.5/1.6/0	64.8/1.2/0	21.4/0.8/0
$P_e(PB)$ (%)	0/0/0	12.9/1.3/0	58.9/49.9/45.7	82.4/45.0/39.4	30.5/1.7/0.2
$P_e(E)$ (%)	1.2/0/0	69.1/71.2/71.9	99.7/98.2/99.5	99.4/97.4/99.6	70.4/59.9/60.3

Adaptation Multiuser Diversity

- wireless channel fading
- The reverse link video transmission can be more efficient if an MS stops transmission when its channel quality is poor.
  - Power consumption
  - Interference to neighbor cell
- Each MS in a bad channel state stays dormant , and gets compensated when it has a good channel state.
- If a video MS is in a bad channel state for a relatively long period, its packets will be discarded as it has to postpone transmission until the channel changes to a good channel state.

Conclusions

- the proposed link layer DWGPS resource allocation benefits from the application layer information such as the batch class and batch arrival size, and in return, the link layer tries to provide the application layer with a stringent delay bound and a strong protection to high priority traffic classes in the case of resource shortage.
- procedure for DWGPS is proposed, which uses only per-batch information and avoids complex per-packet virtual time calculation.
- The DWGPS resource allocation can automatically adapt to multiuser diversity without many modifications.