ATM Traffic Management and Multiple Access in a Wireless LMDS Access Network

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OUTLINE

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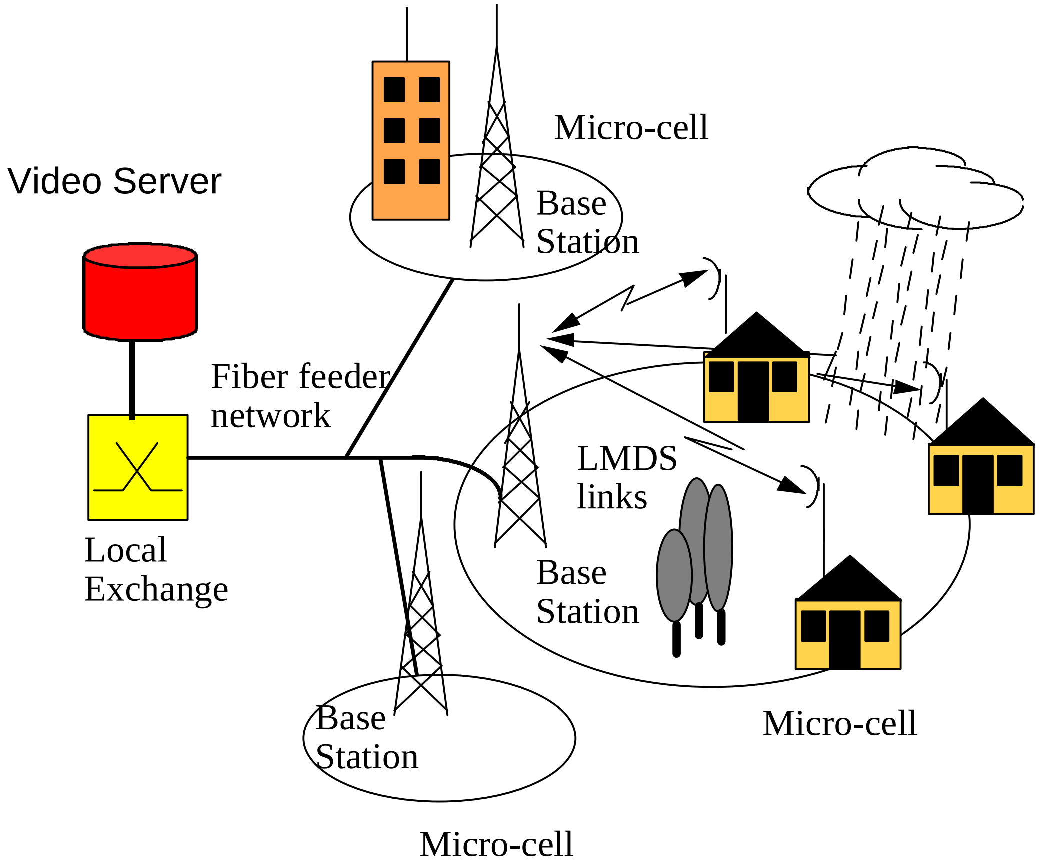
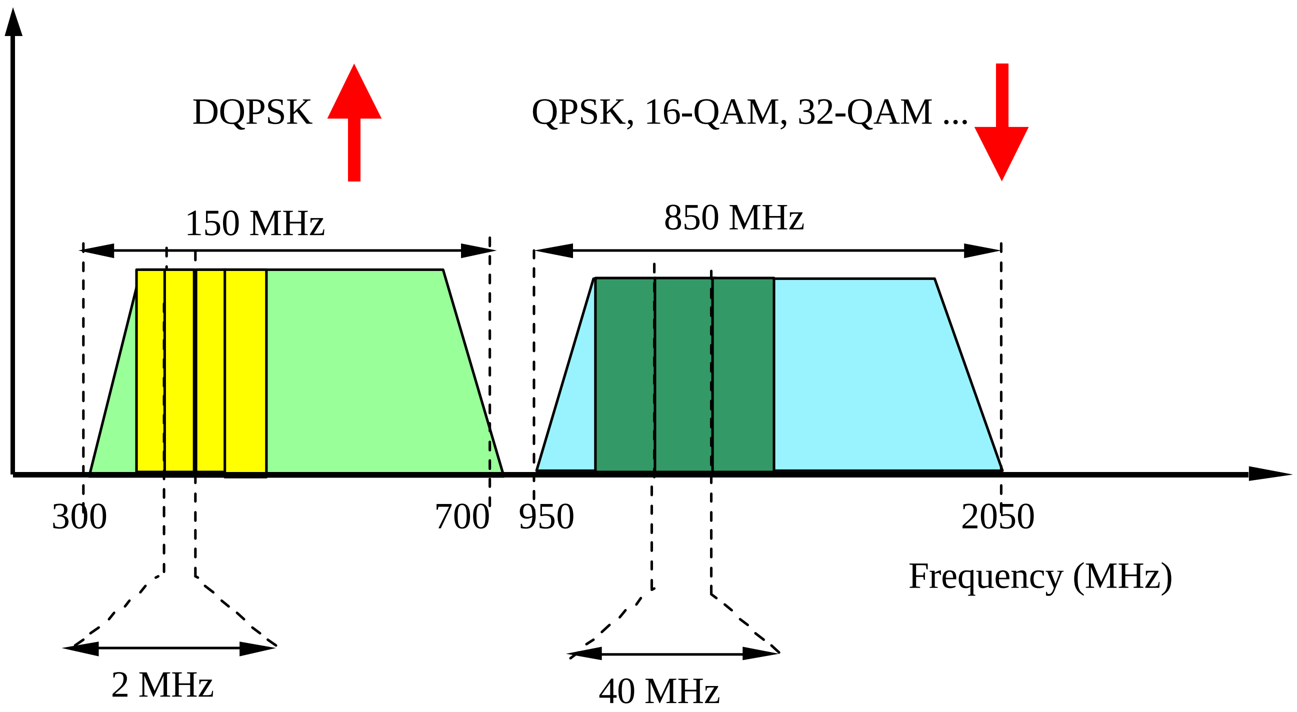
1/7 : Introduction : LMDS market and standardization

- European context :
  - Copper wire unbundling limited to Germany and Sweden
  - National regulation bodies open the WITL market for the end of 2000
- Which market for LMDS in Europe ? :
  - Two variants :
    - » 3,5 GHz : bandwidth of 500 Mhz for residential and SOHO
    - » 26 GHz : bandwidth of 1 GHz for SME
- Standardization bodies :
  - LMDS-DAVIC (de facto standard)
  - LMDS-ETSI

Configuration of an LMDS local loop



Bandwidth allocation for LMDS

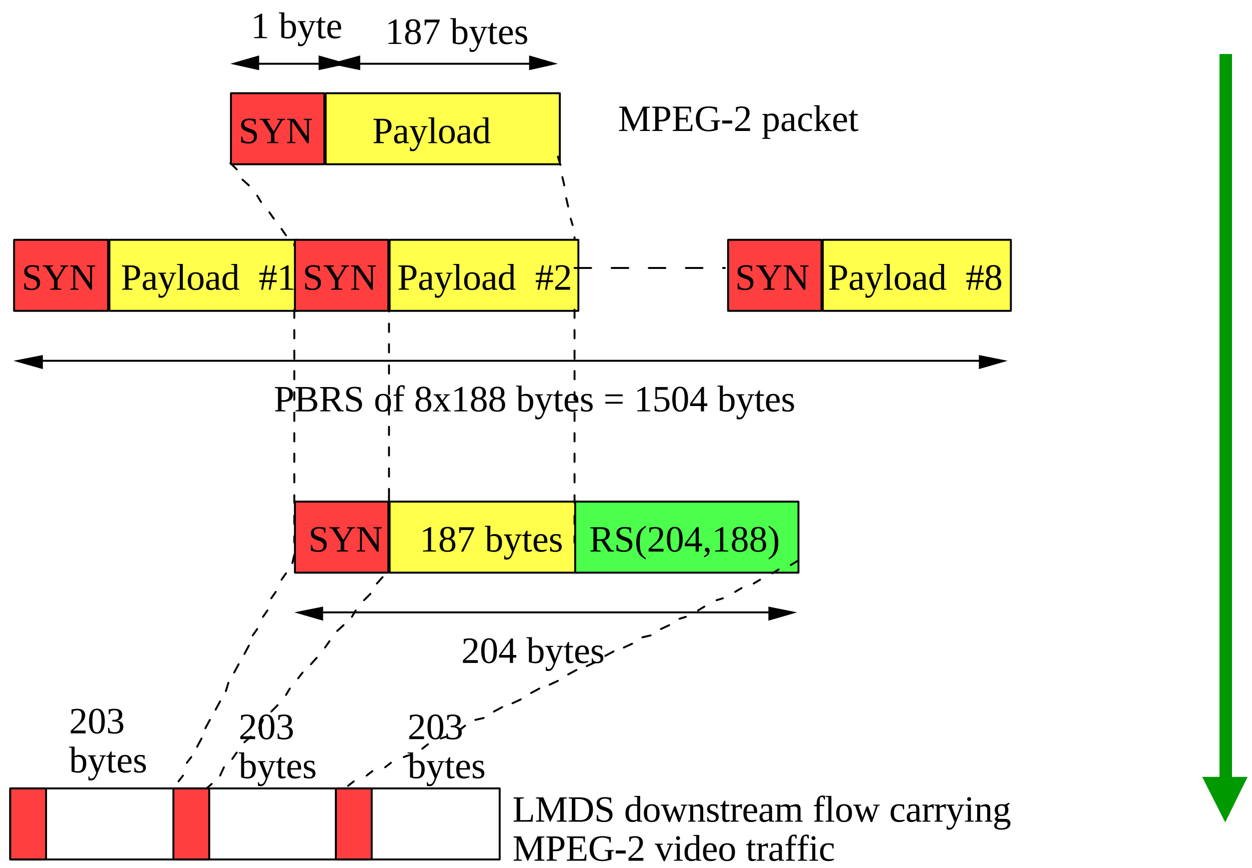


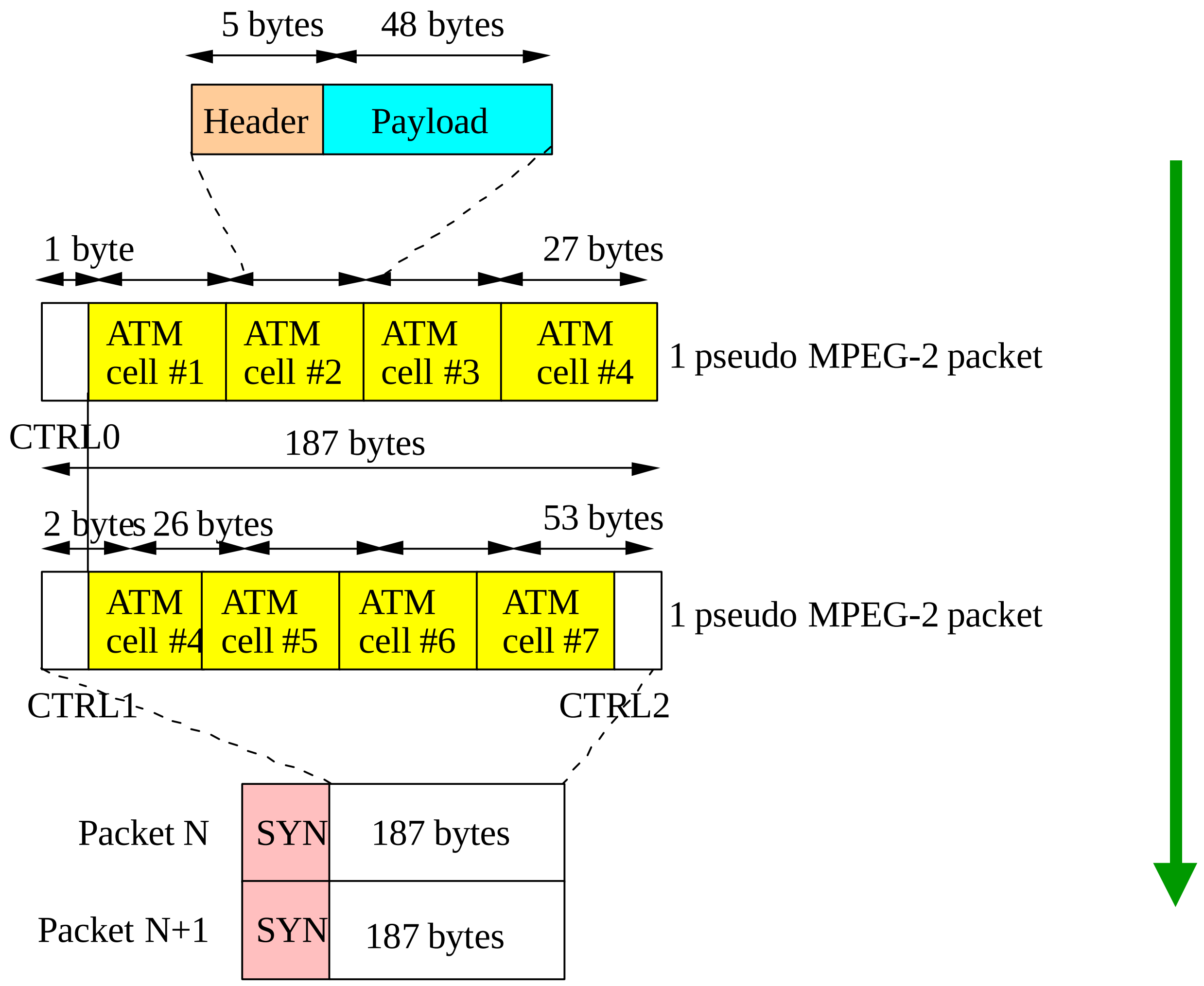
Up to 2 Mbit/s per user **Up to 45 Mbit/s per user**

2/7 : The LMDS MAC-PDU formats

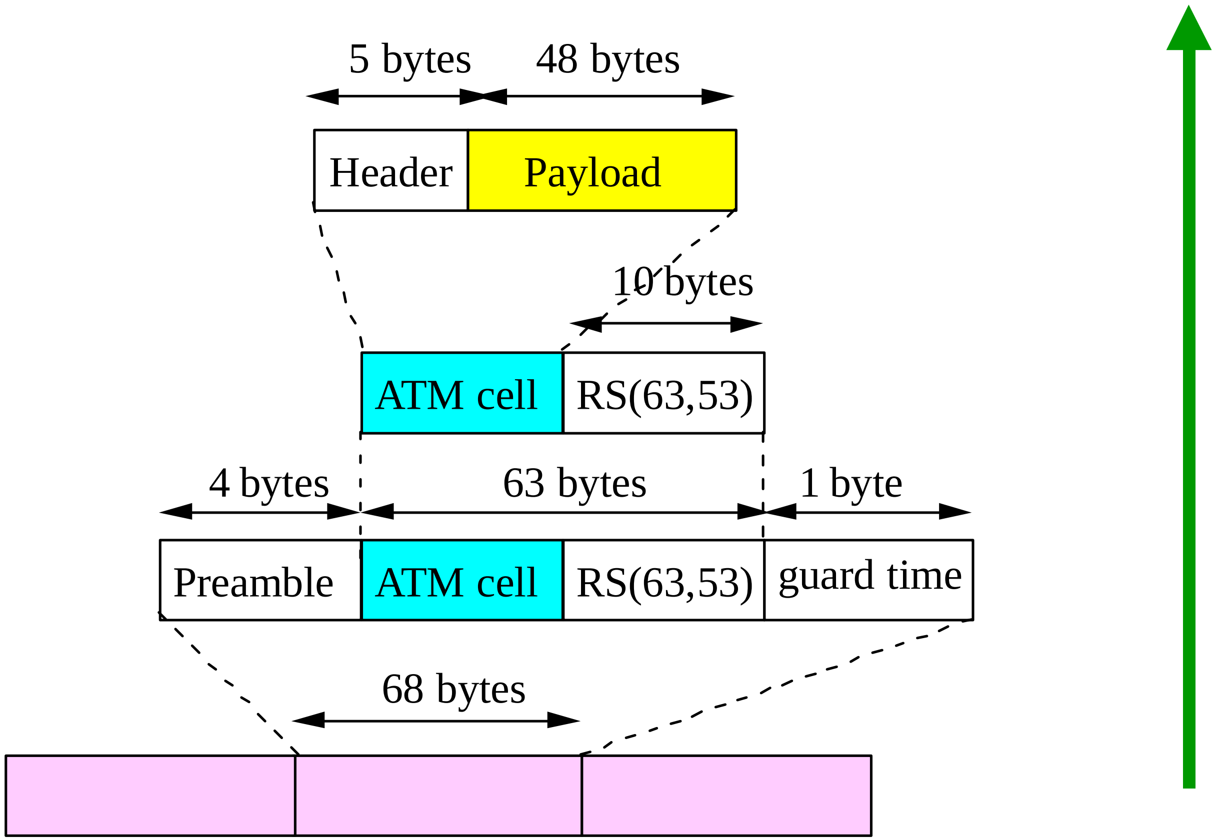
- Downstream direction :
  - MPEG2 frames carrying :
    - Digital video frames (specific channels)
    - ATM cells (data + signaling)
- Upstream direction :
  - ATM slots carrying ATM cells (data + signaling)

Downstream MAC PDUs format




5 bytes
48 bytes
Header
Payload
1 byte
27 bytes
ATM cell #1
ATM cell #2
ATM cell #3
ATM cell #4
1 pseudo MPEG-2 packet
CTRL0
187 bytes
2 bytes
26 bytes
53 bytes
ATM cell #4
ATM cell #5
ATM cell #6
ATM cell #7
1 pseudo MPEG-2 packet
CTRL1
CTRL2
Packet N
SYN
187 bytes
Packet N+1
SYN
187 bytes

Upstream MAC PDUs format



LMDS upstream flow

3/7 : LMDS-DAVIC frames

- 3 types of slots in the upstream direction :
  - Contention [C]
  - Reserved [R] (or [NIU])
  - Polling [P] : every 2 seconds the AIU polls all the inactive NIUs

- Remark : no piggy-backing
- Downstream frames carry 728 ATM cells in 5.819 ms
- Upstream frames carry 24 ATM cells in 6 ms
- NIU synchronization with the AIU is carried out by means of Frame Start slots [FS]

4/7 : Unspecified points in the standards and proposals

- In both DAVIC and ETSI standards, the following points are open to discussion or under the responsibility of the implementers :
  - Bandwidth request strategy by the NIUs :
    - » Identified or anonymous requests ?
    - » Isolated of grouped requests ?
    - » Polling or piggy-backing ?
  - Bandwidth allocation strategy by the AIU :
    - » Identified or anonymous permits ?
    - » Isolated or grouped permits ?
  - Contention slots allocation strategy
  - Contention resolution algorithm

Proposal #1 : the Immarsat contention resolution algorithm :

- The algorithm is activated as soon as none positive acknowledgement is received after a transmission in [C] slot
- Let *R* be a variable equal to 0, 1, 2 or 3 according to the 4 possible states (a state corresponds to the amount of observed collisions) of a NIU
- Let *n* be the amount of upstream frames after which a NIU is authorized to re-attempt a transmission in a [C] slot, *n* belongs to $[0, 3^R]$
- Initial values : $R = 0$ and $n = 0$

- At the beginning of every upstream frame :

```
If (n = = 0) then {
        If a [CS] cell is waiting for transmission then {
                Choose randomly one of the [CS] slots in the frame
                R = Max(R + 1,3)
                n = Rand[0..3^R]
        }
        Else : do nothing;
}
Else {
        n = n - 1
}
```

- At the receipt of a contention-slot-feedback :

    If (positive Ack) then {

        $R = 0$

        $n = 0$

    }

    Else

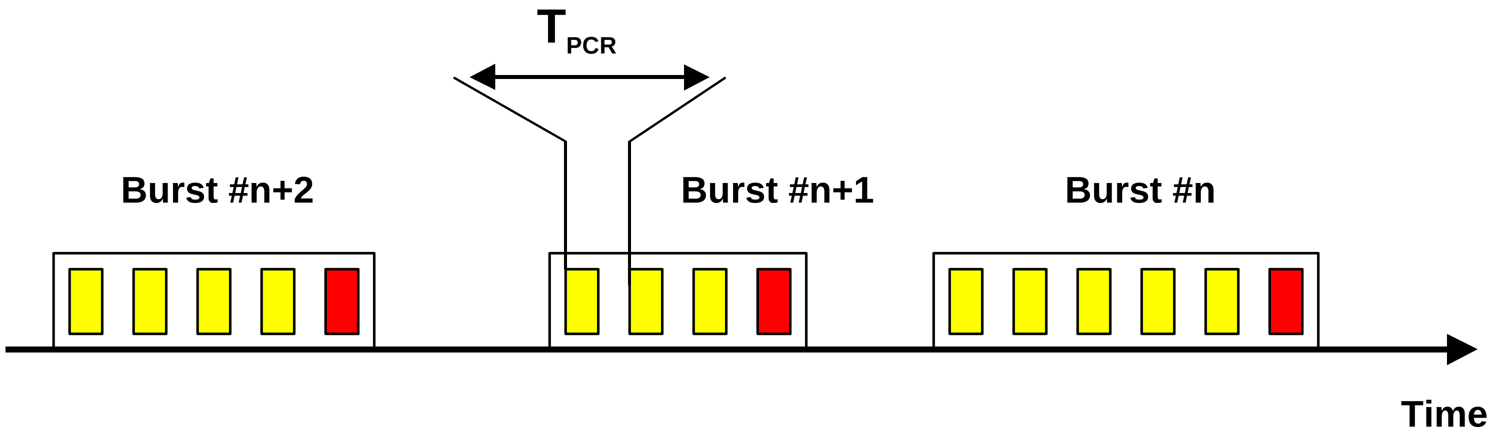
        Do nothing

- The maximum delay between two successive transmissions of a the same cell is $3^3 = 27$ frames

Basic principles for dynamic bandwidth allocation in LDMS-DAVIC

- The AIU must get knowledge of the ATM traffic contracts in order to serve bandwidth requests accordingly
- Two alternatives are possible for that purpose :
  - The AIU intercept Q.2931 signaling cells
  - The AIU relies on the BCCP (Broadband-Bearer Control Protocol) defined in VB5.2 interface specifications
- For a given connection, a bandwidth request is sent by a NIU in a [C] slot at the beginning of a each burst at the PCR
- Bandwidth reservation is carried out until the AIU receives a non-utilized reserved slot

Proposal #2 : the burst merging mechanism



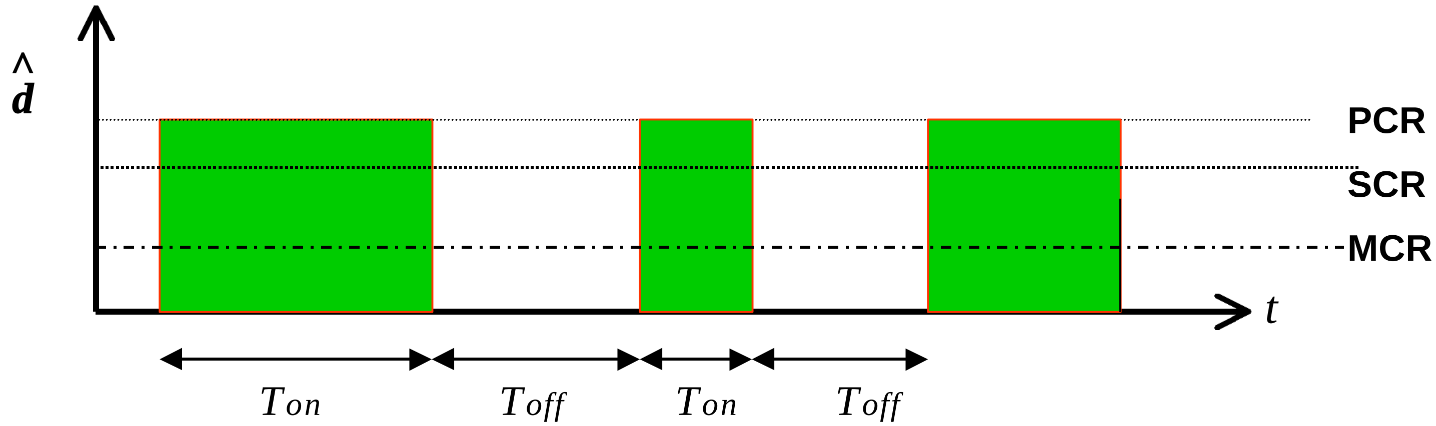
- The higher the burstiness of a connection, the higher the mean access delay
- Idea: for a given connection, if a new burst is generated whereas the previous burst has not been completely transmitted, the transmission of a new bandwidth request is useless

Proposal #3 : number N_C of contention slots

- Several alternatives are open in the LMDS-DAVIC standard :
  - 1: statically
  - 2: dynamically according to the number of observed collisions
  - 3: proportionally to the amount of active NIUs
- Our choice :
  - Option 3 with 15% of de NIU actives

5/7 : VBR and GFR traffic sources modeling

- **On-Off sources for VBR connections** :



- Applications : paquetized voice, video traffic with adaptive coding
- 3 traffic descriptors :
  - Peak cell rate $\hat{d}$ (PCR)
  - Sustainable cell rate (SCR)
  - Burstiness : $B = (Ton + Toff) / Ton \geq 1$

- Exponential distribution of parameter λ for burst duration
- The value of T_{on} is set in order to regulate the burst merging phenomenon occurrence :

$$\frac{1}{l} = 60.Min[T_{on}]$$

where Min[T_{on}] stands for the duration of an ATM cell at the PCR

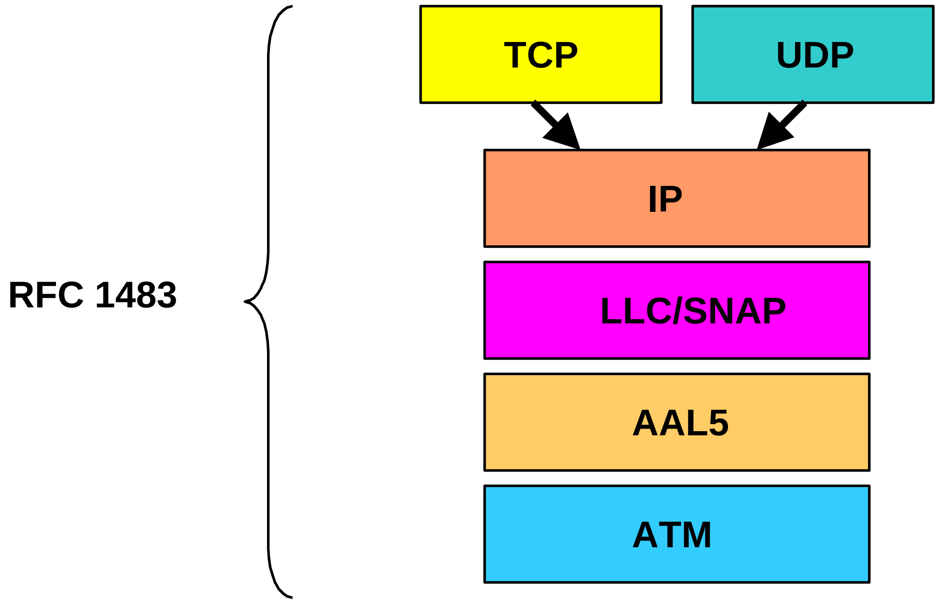
- A worst case traffic is considered by imposing a transmission at the SCR between two successive bursts :

$$SCR = \hat{d} \cdot \frac{1}{B} = PCR \cdot \frac{T_{on}}{T_{on} + T_{off}}$$

- For that purpose, the value of T_{off} is set deterministically :

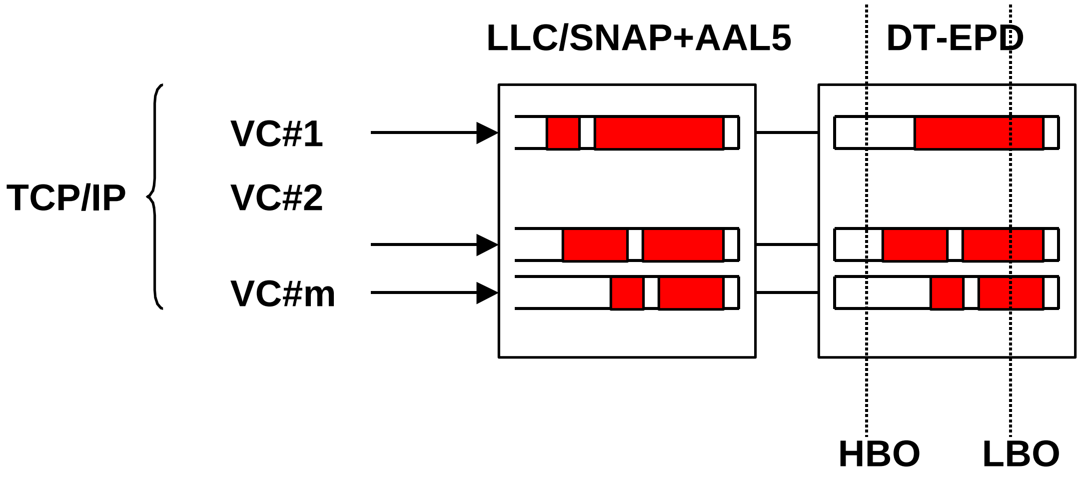
$$T_{off} = \frac{PCR \cdot T_{on}}{SCR} - T_{on}$$

- **Traffic sources for GFR connections** :
- Application : transport of TCP/IP elastic traffic :
  - Several options for TCP/IP over ATM :
    - » RFC 1483, RFC 1577 (classical IP over ATM), LANE, MPOA,
  - Choice : RFC 1483
  - GFR guarantees :
    - » a Minimum Cell Rate (MCR) to TCP/IP connections
    - » a fair share of gratis bandwidth between TCP/IP connections



- TCP/IP messages distribution based on real statistics
  - MinSize = 64 bytes, MaxSize = 1518 bytes, MeanSize = 368 bytes
- Message inter-arrivals according to an exponential distribution :

- In order to guarantee for each TCP/IP connection the negociated MCR and an upper bound on cell transfer delay, we implemented the Dynamic-Threshold Early Packet Discard algorithm (DT-EPD)



- For NIU # i, bandwidth reservation based on the cumulated MCR of the connections j :

$$R(i) = \sum_j MCR(i, j)$$

Proposal #4 : gratis bandwidth is fairly distributed between the active GFR connections among the active NIUs

- Let *S(i)* be the gratis bandwidth for NIU # *i*:

$$S(i) = \frac{C - \sum_{i=1}^{N} \sum_{j} PCR^{*}(i,j) - \sum_{i=1}^{N} \sum_{j} MCR^{*}(i,j)}{N^{*}}$$

- For NIU # *i*, bandwidth reservation based on the cumulated MCR of the connexions *j* :

C : Upstream channel capacity
*N** : Amount of active NIUs in terms of GFR connections
PCR(i,j)* : PCR of an active VBR connection # *j* in NIU # *i*
MCR(i,j)*: MCR of an active VBR connection # *j* in NIU # *i*

- Remark :
  - Even if it knows all the active ATM connections, the AIU is not able to address individual connections because LMDS-DAVIC MAC messages do not include VPI.VCI (3 bytes)

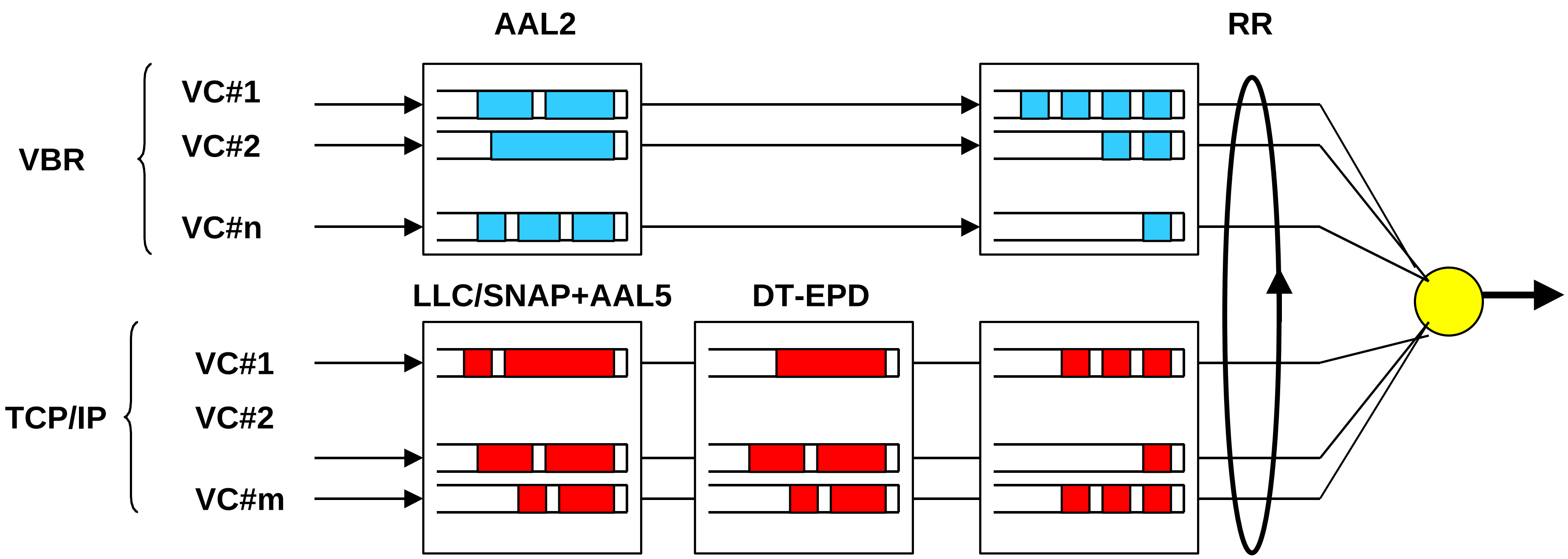
- Gratis bandwidth is allocated to the NIU au proprata of the weight of the cumulated MCR of their GFR connections :

$$S'(i) = S(i).\frac{\sum_{j=1}^{k} MCR^{*}(i,j)}{\sum_{i=1}^{N*}\sum_{j=1}^{k} MCR^{*}(i,j)}$$

$$\sum_{i} S'(i) = S(i)$$

Proposal #5 :buffer management and scheduling at the NIUs

- Per-VC queueing and scheduling at the NIUs

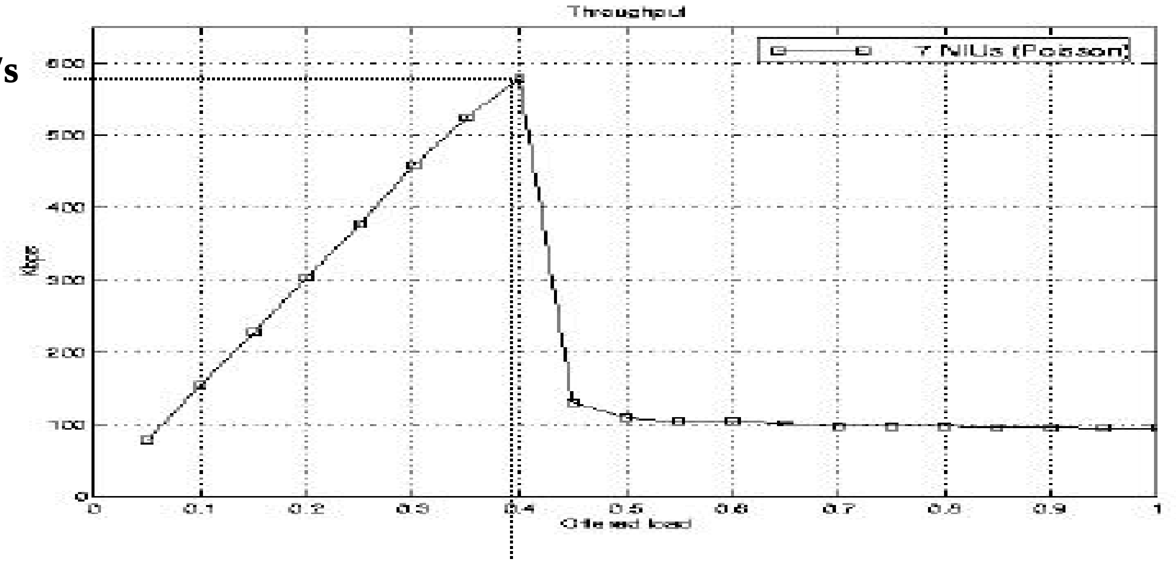


- Scheduling at the AIU : fair distribution of gratis slots to the NIUs

6/7 : Simulation results

- Assumptions :
  - Ideal upstream/downstream radio channels
  - A single upstream channel is considered (among 205 channels)
  - NIUs are equidistant from the AIU
  - Channel bit rate : 2.2436 Mbit/s (LMDS-DAVIC)
  - ATM upstream rate :1.749 Mbit/s
  - A single voice connection per NIU
- Bandwidth is reserved at the AIU :
  - On the basis of PCR for VBR connections
  - On the basis of MCR for GFR connections
- 32 kbit/s ADPCM G.726/G.727 voice traffic (42 kbit/s with AAL2/ATM overheads)

580 kbit/s

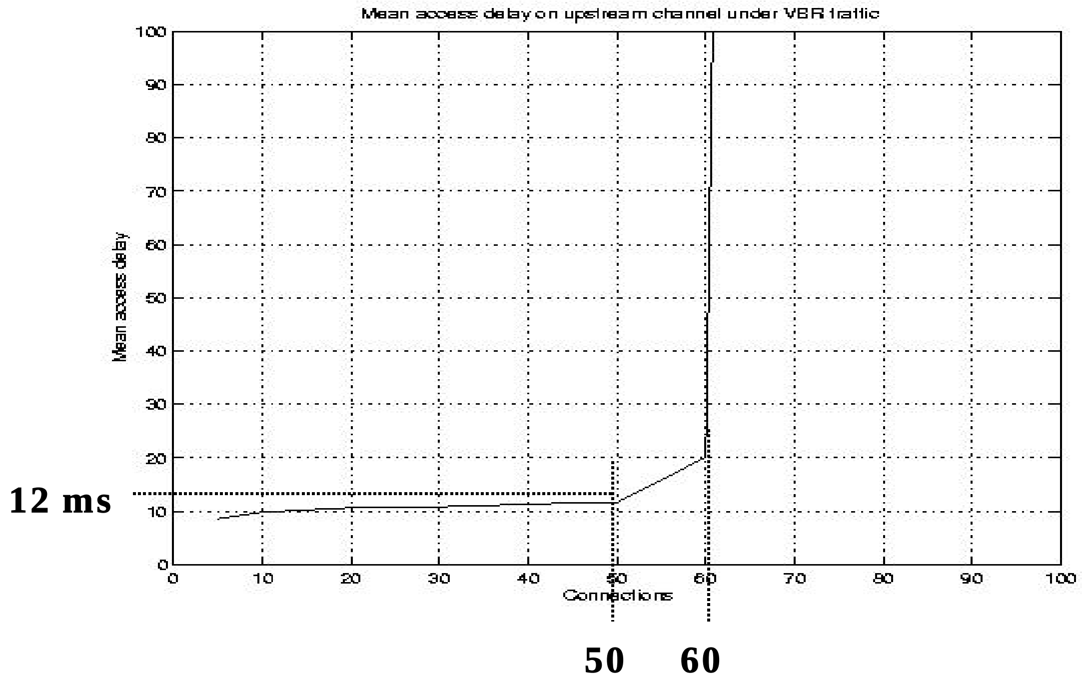


40%

MAC Protocol efficiency in the worst case (nrt-VBR data traffic, every cell is [C])

Cell capacity in number of voice connections

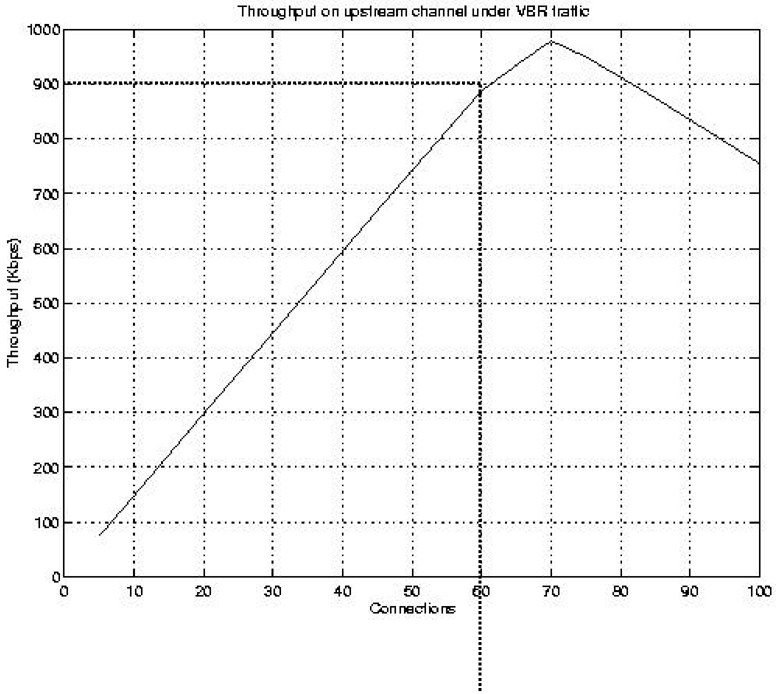
- Choice : upper bound on cell tranfer delay through the LMDS loop : 12 ms



Mean access delay versus the amount of active NIUs (1 voice connection per NIU)

- 50 voice connections/channel ; around 10.250 calls per cell

900 kbit/s

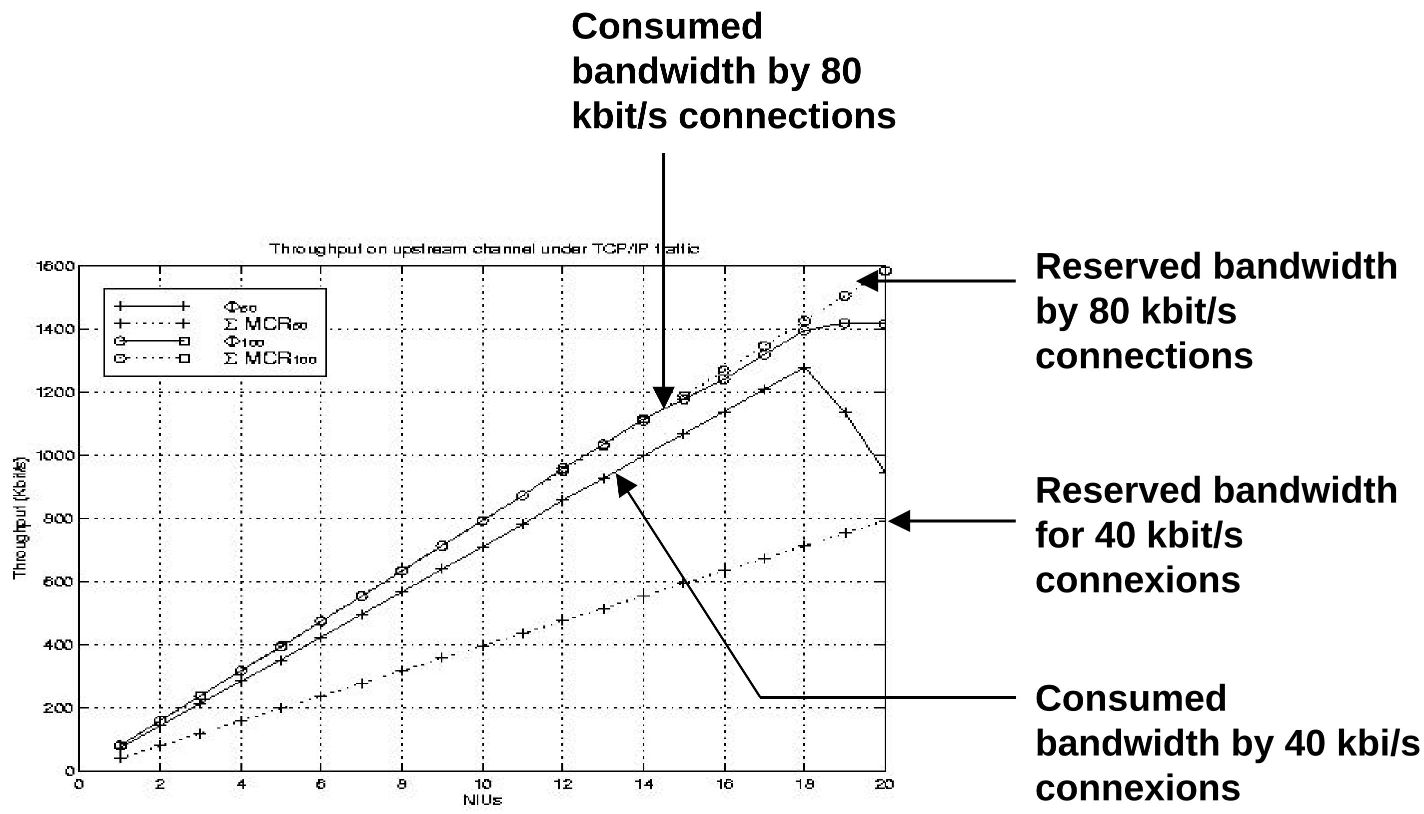


60

Aggregated goodput versus amount of active NIUs (1 voice connection per NIU)

Cell capacity in number of TCP/IP connections

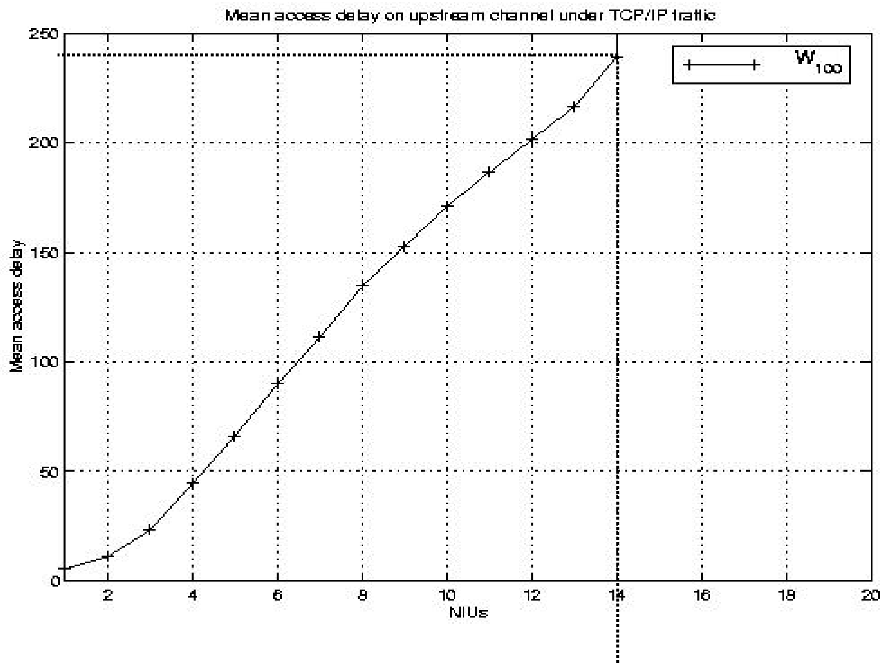
- Each TCP/IP connection generates a load equal to 5% of the upstream channel capacity (1,584 Mbit/s) i.e. 80 kbit/s (Web browsing)
- Two types of MCR:
  - MCR_{100} : MCR = 80 Kbit/s
  - MCR_{50} : MCR = 40 Kbit/s



Aggregated goodput versus TCP/IP offered load (1 TCP connection per NIU)

Dot line : reserved bandwidth; Continuous line : consumed bandwidth

240 ms



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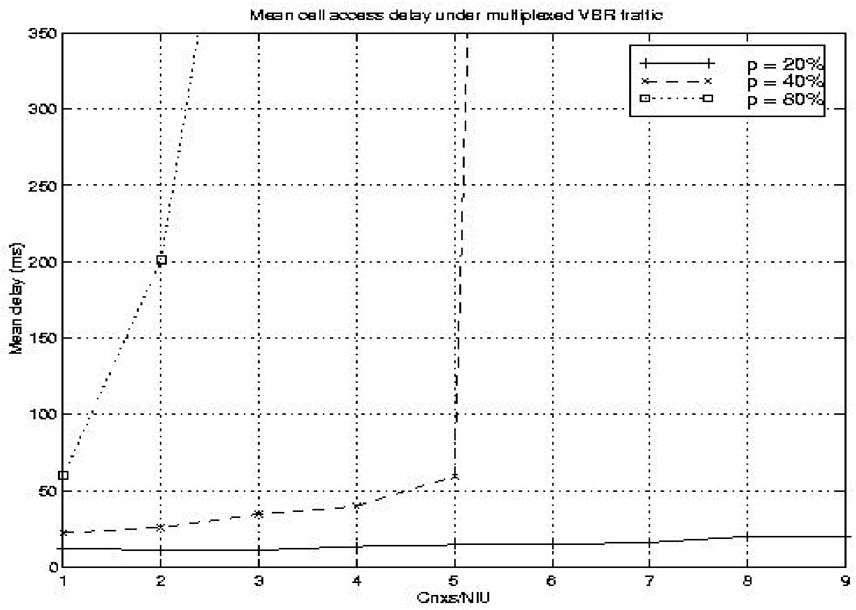
Mean access delay versus TCP/IP offered load
(1 TCP connection at 80 kbit/s per NIU)

Multiplexing of several VBR or of several GFR connections in each NIU

- 8 NIUs generate an aggregated load ρ equal to 20%, 40% ou 80% of the upstream capacity
- Reserved bandwidths are :

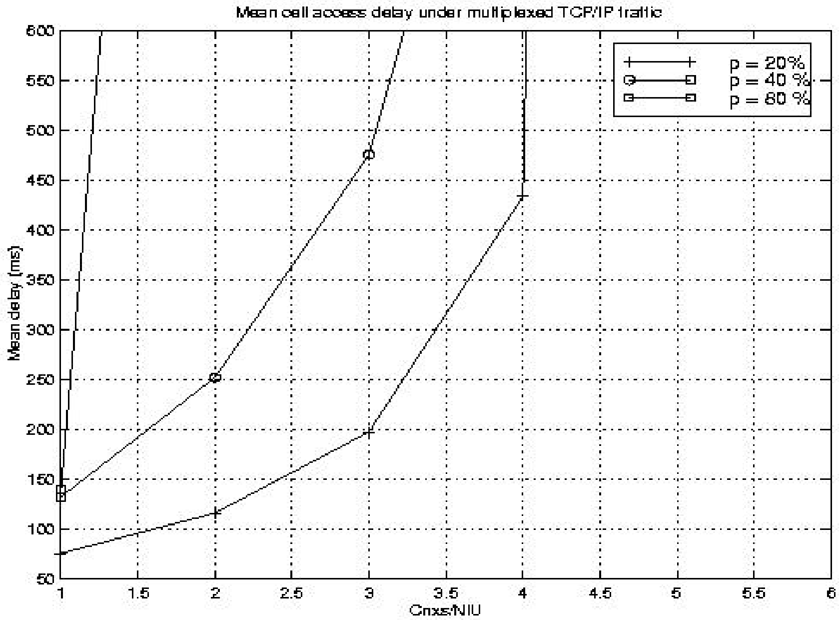
$$SCR_{VBR} = MCR_{GFR} = \frac{C.r}{N_{NIU} N_{connx}}$$

- Objective: what is the maximum amount of connections that can be multiplexed within each NIU ?



Mean access delay versus amount of VBR connections per NIU (8 NIUs)

Strong limitation in the number of voice calls if several voice connections are multiplexed within each NIU



Mean access delay versus amount of GFR connections per NIU (8 NIUs)

Strong degradation in the mean access delay when several GFR connections are mutiplexed within each NIU

CONCLUSION

- In the absence of any other traffic, up to 10.000 voice calls are achievable in a LMDS cell
- Thanks to the GFR transfer capacity, gratis bandwidth is fairly and efficiently allocated between TCP/IP connections
- It seems preferable to distribute multiplexed voice calls in a given NIU over different upstream channels
- Our simulations show that the higher the burstiness of TCP/IP connections, the higher the mean access delay
- The rules to be adopted for contention slots allocation have a strong impact on the QoS of voice connections in presence of TCP/IP connections
- In the round-robin process for slots affectation (reserved + gratis), a higher priority should be dedicated to voice connections than to TCP/IP connections
- The specific MCR and SCR in a given NIU could be satisfied by a weighted roud-robin
- Further studies will investigate the mix of VBR and GFR connections within a same NIU