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How To Ensure QoS in CDMA 2000 EVDO Rev A systems

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Objectives

- **What is QoS and Why is QoS Needed?**
- Ensuring QoS in CDMA 2000 1x EVDO Rev A
- Pre-Deployment Considerations for QoS in 1x EVDO Rev A
- End to End QoS

What is QoS?

- **Quality of Service (QoS)** refers to the capability of a network to provide differentiated service to a selected group of users or for specific types of network traffic over various transport technologies such as:
  - CDMA2000 1x
  - CDMA 2000 1x EV-DO Rev. A air-interface
  - IP networks
- **QoS allows users with different OSI application layer needs to meet their service requirements while utilizing the available system resources efficiently.**

What is QoS (Continued)?

In CDMA 2000 1x voice systems, QoS is tied performance metrics. These may include:

- Blocked Call Rate
- Grade of Service
- MO/MT call setup time
- Dropped call rate
- FER
- Paging Success Rate etc

In this presentation, QoS aspects will be centered around data as 1x Voice networks are quite well understood.

* Further details refer to Qualcomm's 1x ATP & KPI documentation

Why is QoS Needed?

- In a network with infinite resources, the concept of QoS would not exist, nor be needed.
- QoS:
  - Ensures a **consistently** good user experience.
  - Enables new **differentiated** services and classes of service that were previously not feasible.
  - Provides more **efficient resource control** and usage.
  - Supports **tailored services** for operator differentiation.
  - Allows **coexistence of business-critical** applications alongside interactive multimedia and voice applications.
  - Is the foundation of the fully integrated network of the future.

QoS Application Categories

- **The majority of** wireless applications **can be divided into three major categories:**
  - **Expedited Forwarding** – Delay-sensitive (e.g., VoIP, VT-audio)
  - **Assured Forwarding** – Rate-sensitive (e.g., Video streaming)
  - **Best Effort** – Delay-tolerant (e.g., FTP, HTTP)
- **3GPP2 further classifies the categories as:**
  - **Conversational, Interactive, Streaming, and/or Push-to-X**
  - **Which are further classified by applications:**
    - **Video, Audio, Speech, Signaling, Text, and Gaming**

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Ensuring QoS in 1xEV-DO Rev A

- Forward/Reverse Links
  - **Link efficiency**
    - Header compression and link flows
  - **Admission control**
- Forward Link
  - **Queue management via scheduling algorithms**
    - Proportional Fair and Delay Fair
  - **Congestion avoidance and policing**
    - Random Early Detection (RED), Weighted RED, and Tail Drops
- Reverse Link
  - **Traffic Shaping**
    - Token-bucket algorithm

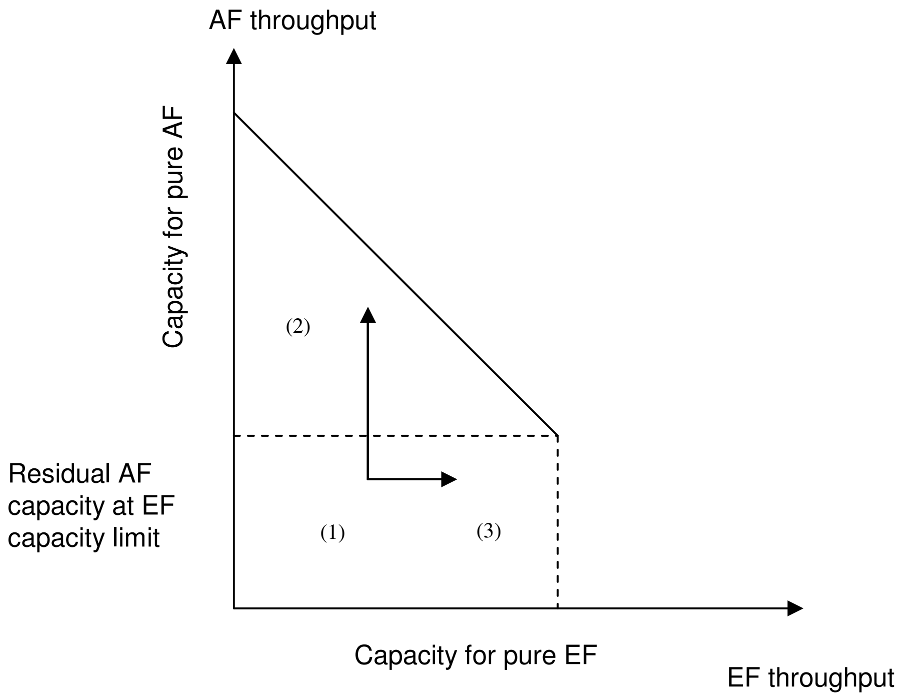
Link Efficiency via EMPA

- In 1xEV-DO Rev A, link efficiency is achieved via the Enhanced Multi-Flow Packet Application
  - **Spectral Efficiency**
    - **Packet-based RLP** – EMPA enables packet streams that can carry packets between the Access Terminal and the Access Network. Packet-based RLP reduces the overhead.
    - Single VoIP frame can be encapsulated in a single air-interface frame, by utilizing **Robust Header Compression** (**RoHC**).
  - **Inter-RNC Handoff**
    - Two parallel routes can be terminated at different RNCs simultaneously, minimizing interruption in the voice stream due to Inter-RNC handoff.

Admission Control at the RAN

- The 1xEV-DO Rev. A RAN may perform admission control techniques to maintain QoS

- Admission Control – **A technique to “block” or deny an incoming QoS flow request in order to satisfy QoS requirements with a very high probability**



(1) current operating point
(2) new operating point with a new AF flow
(3) new operating point with a new EF flow

- A strict limit must be maintained on the amount of QoS traffic in the system.
- Relies on QoS profiles of the incoming and existing QoS flows.
- Admission decision based on if total QoS class traffic is within the capacity region.

Forward Link QoS via Scheduler

- In 1xEV-DO Rev A, Forward Link QoS at the AN may be maintained via the scheduler.
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  QoS and serving of users is based on:
  - **QoS requirements for flow** – Delay bound, throughput, and reliability.
  - **Priority of application flow**
    - Best Effort, Assured Forwarding, Expedited Forwarding
    - AND/OR Priority Level 0 – 7
  - **Amount of data in Forward link queue**
  - **Channel conditions of AT**
  - **Number of active users in the sector**

Priority Levels and Classes

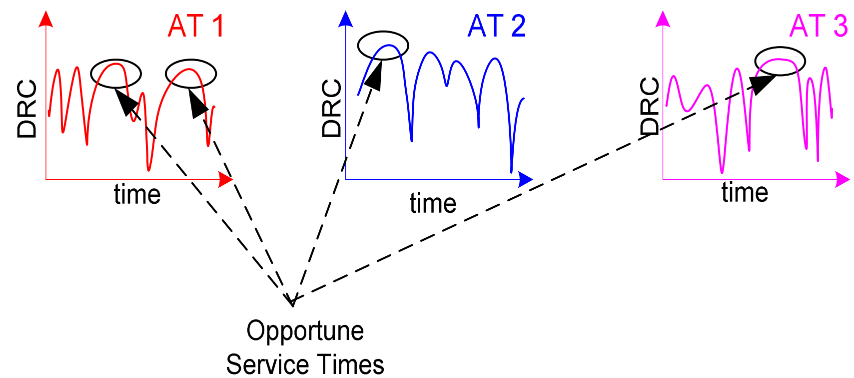
- QoS priorities can be divided into 8 groups:
  - QoS priority level increases from 0 – 7.
  - An IP flow for a specific type of application data can be assigned a priority.
  - The QoS regulator uses these values to prioritize traffic.
  - **Priorities can be set by the operator with help of the Vendor.**

Example

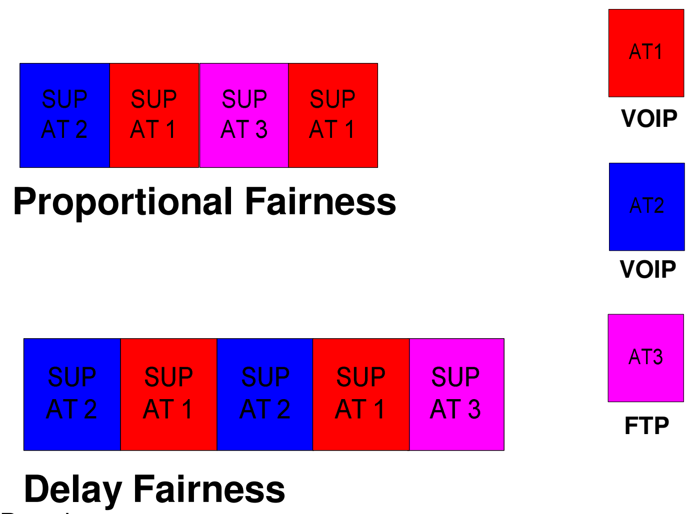
Priority Level	Traffic Type
0	Best Effort
1	Background
2	Standard (Spare)
3	Excellent Load (business critical)
4	Controlled Load (streaming multimedia)
5	Video (interactive media) <100 ms latency and jitter
6	Voice (interactive voice) <10 ms latency and jitter
7	Network Control Reserved Traffic lowest latency and jitter

Queue Management via Scheduling Algorithms on the Forward Link

- Proportional Fairness (Best Effort flows)
  - Exploit variations in the channel quality of users (multi-user diversity).
  - Average user throughput is roughly in proportion to DRC.
  - As load increases, BE flows suffer even degradation.

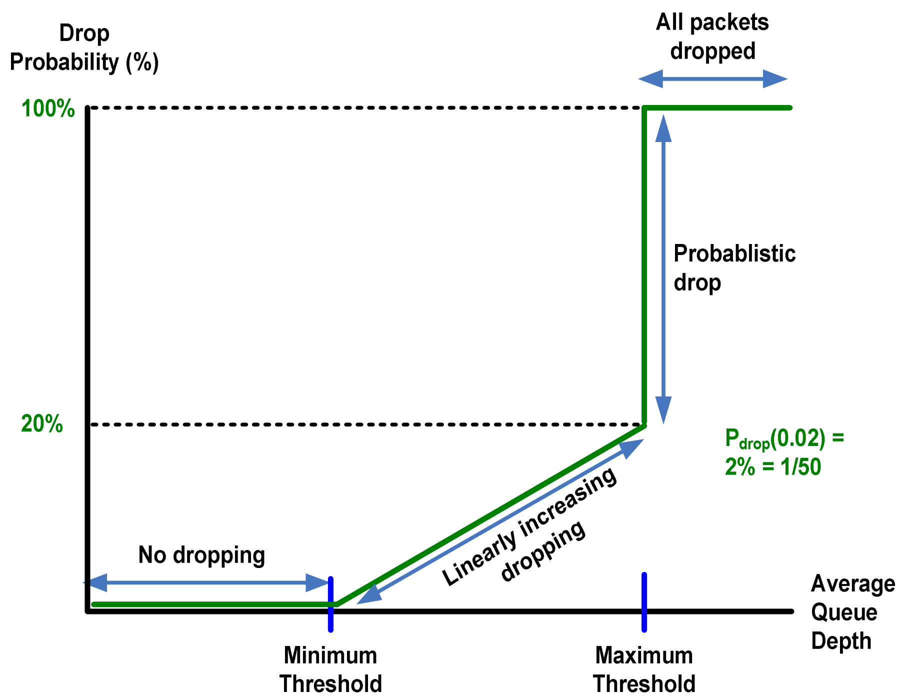


- Delay Fairness (QoS flows)
  - Maintain appropriate priority for various QoS flows.
  - Inverse relationship between a user’s channel condition and the delay statistics of its flows.
  - Uneven degradation across flows should occur.



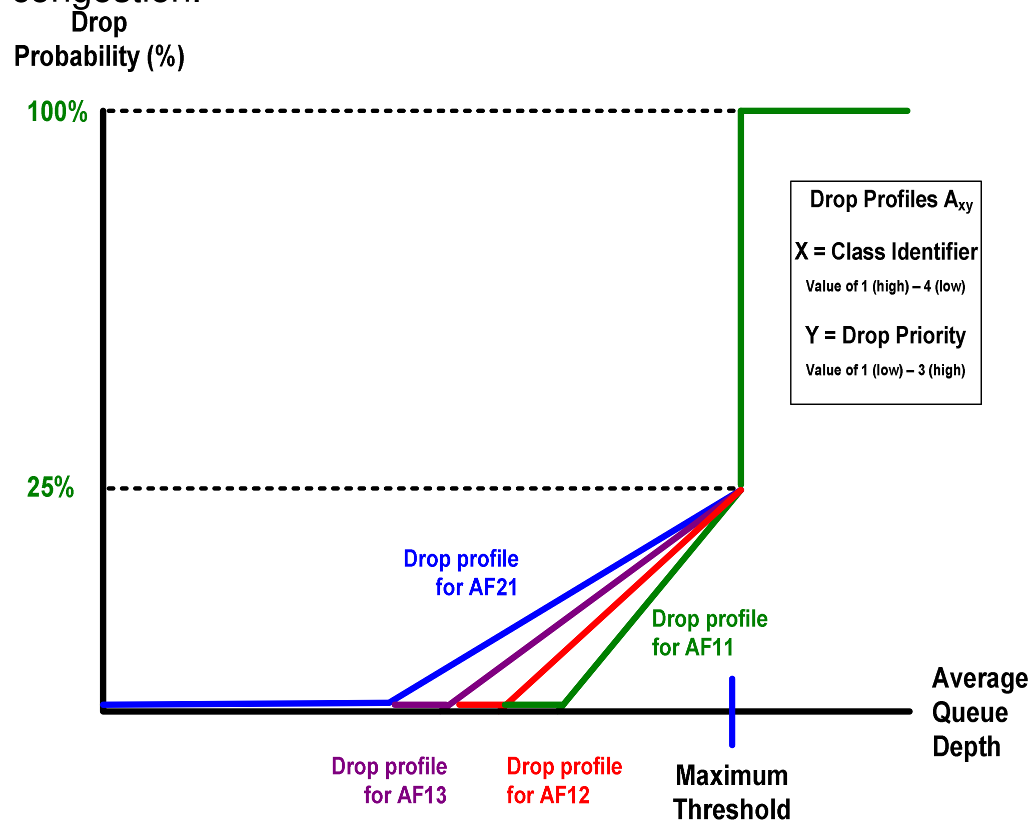
Congestion Avoidance Algorithms on the Forward Link with RED

- Random Early Detection (RED)
  - Drops packets incoming to the queue, based on statistical probabilities.
  - Gracefully slows a congested link, preventing global synchronization.
  - Considers three values: **Min Thresh**, **Max Thresh**, and **Drop Probability**.
  - Intended for Best Effort type traffic, or on interfaces where congestion is likely.
  - Typically used when a single queue buffer exists.



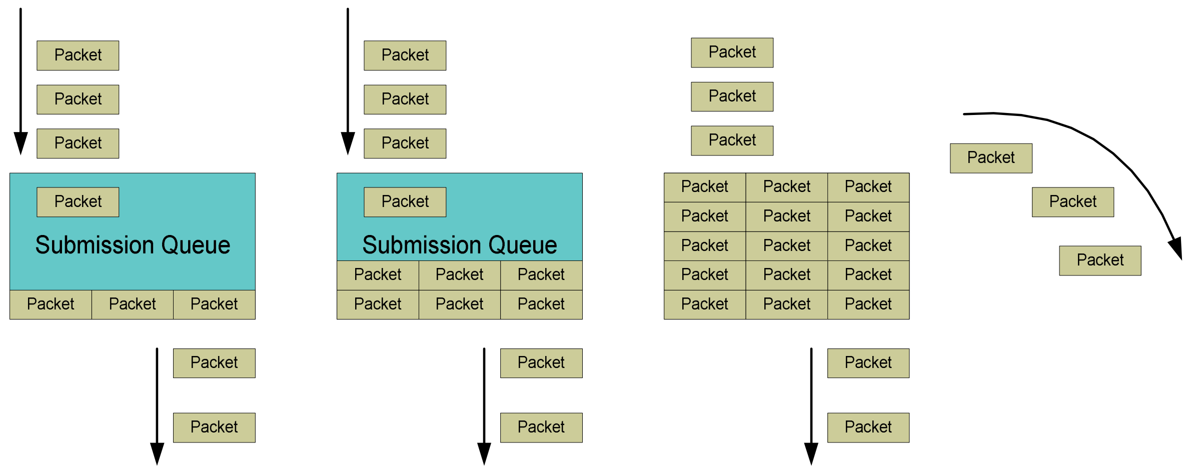
Congestion Avoidance Algorithms on the Forward Link with WRED

- Weighted Random Early Detection (WRED)
  - Uses capabilities of RED, with IP precedence.
  - Selectively discards lower priority traffic during congestion.
  - Attempts to anticipate and control congestion.
  - Considered parameters for each traffic class or weight:
    - **Min thresh**
    - **Max thresh**
    - **Drop probability**
  - Drops more packets from large users rather than small.
  - Useful for Assured Forwarding type flows.



Congestion Avoidance Algorithms on the Forward Link with Tail Drops

- Tail Drops
  - All traffic is treated equally
    - there is no difference between class of service
  - Queues are quickly filled during congestion periods
  - When the queue is full, packets are dropped from the tail until the queue is no longer full
  - Considers a single parameter: **Packet Drop Threshold**
  - Useful for Expedited Forwarding types of traffic



Revision A Reverse Link MAC Enhancements

- Design Goal: **Effective support for symmetric delay-sensitive applications, while balancing a trade-off between capacity and latency and ensuring QoS of various flows achieved at high system stability.**
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Revision A Reverse Link MAC Enhancements

- **Physical and MAC layer Reverse link Hybrid-ARQ**
- **Early termination and new payload sizes**
  - Higher data rates through larger payload sizes for delay-tolerant applications
  - Lower latencies through smaller payload sizes for delay-sensitive applications
- **Comprehensive AN control of AT resource allocation**
- **QoS sensitive resource allocation across multiple flows**
- **Trade-off per flow between capacity and latency**
- **Improved Reverse link system stability at higher RoT operating points**

Reverse Link QoS

- In 1xEV-DO Rev A, Reverse link QoS is maintained by the AT and the RTCMAC Algorithm.
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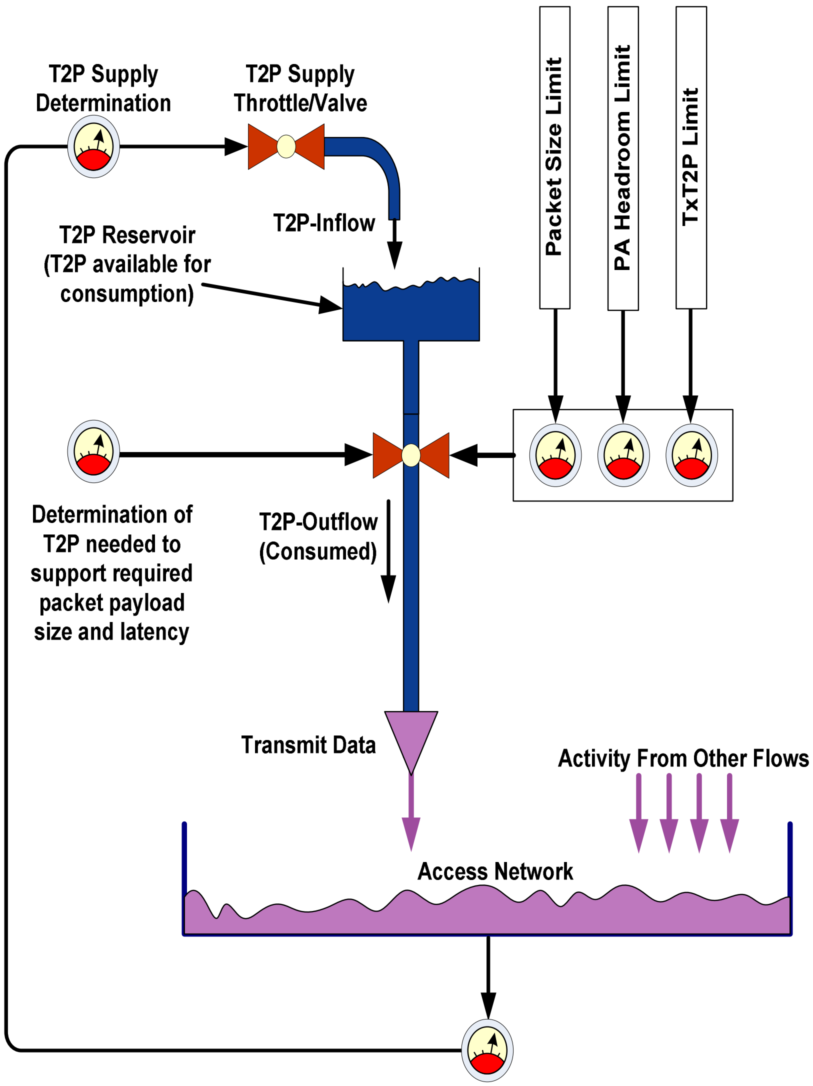
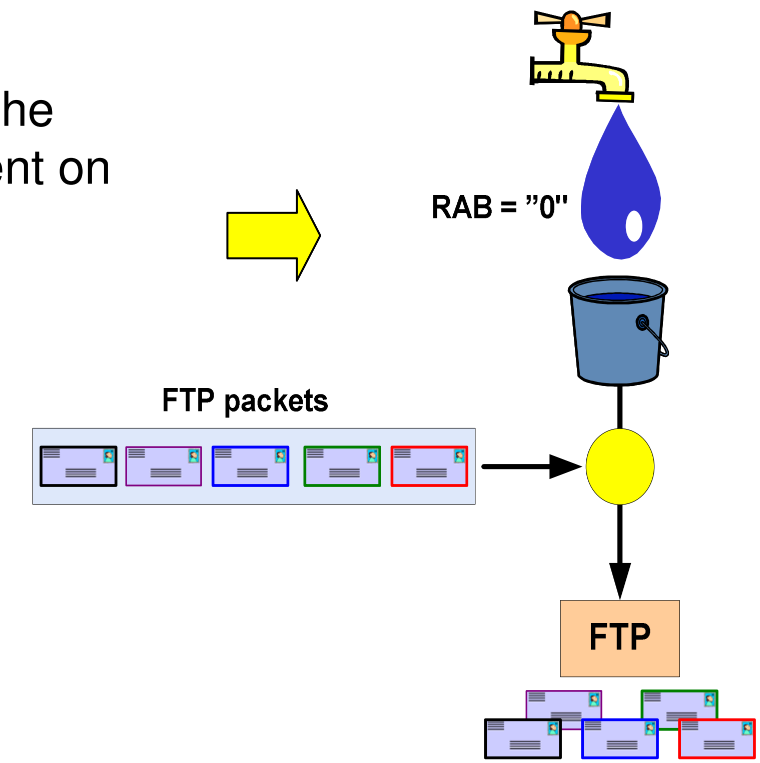
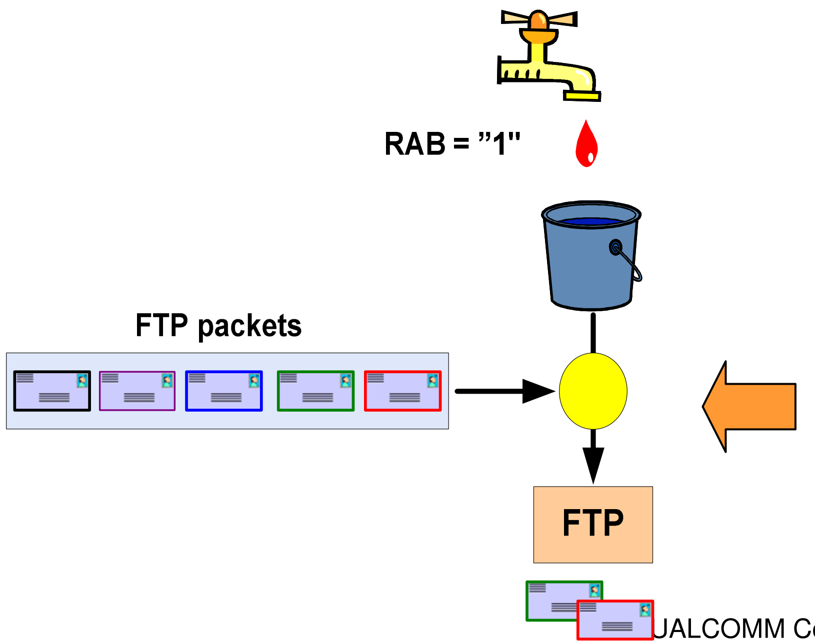
  QoS and flow transmissions are based on:
  - QoS requirements of flow
    - Payload size, delay bound, etc.
  - RTCMAC flow priority functions
  - Amount of data in Reverse link queues
  - Channel conditions of AT and sector loading
  - Available T2P resources



Token Bucket Algorithm

1. Best Effort transmission when RAB = “0”. The number and size of packets sent is dependent on the bucket level. More packets and larger payloads can be sent as the bucket level increases.

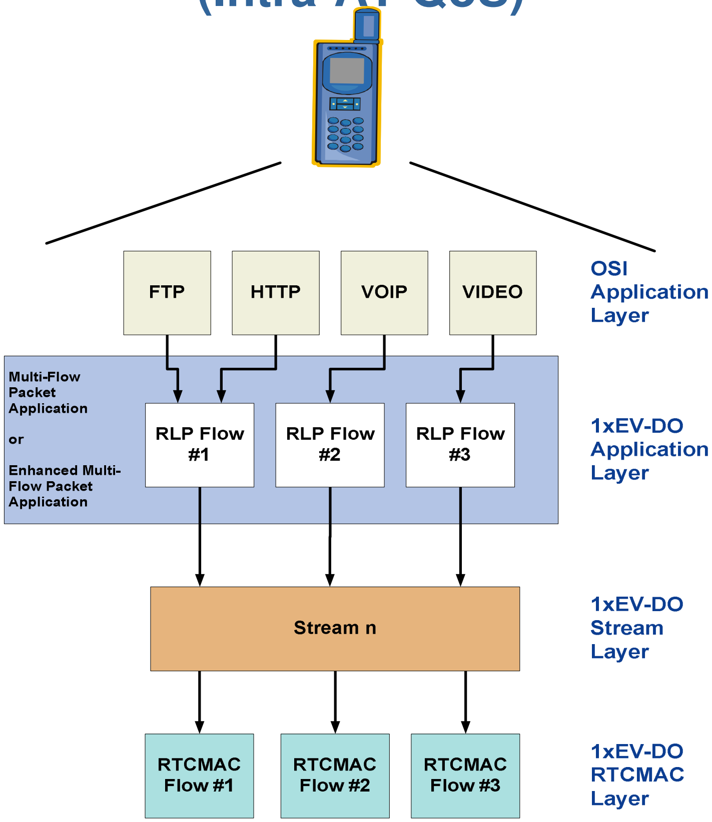




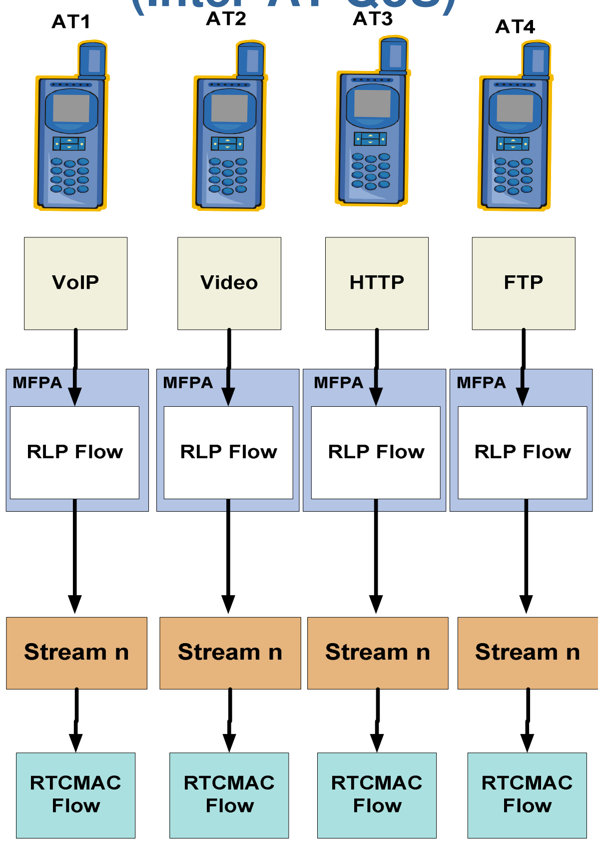
2. Best Effort transmission when RAB = “1”. In this case, **fewer** packets and smaller payloads can be sent as the bucket level increases at a slower pace, due to loading.

Reverse Link QoS

Multiple Flows per AT (Intra-AT QoS)



Single Flow per AT (Inter-AT QoS)



Intra-AT QoS

- **Intra-AT QoS support** is facilitated by the use of **multiple MAC flows per AT**.
  - MAC parameters control allocation for each data flow at each AT.
  - Performance of delay-sensitive flows is unaffected by delay-tolerant data flows.
  - MAC flow behavior is uniform for an AT and across ATs.
  - AT resource allocation is the sum of its MAC flow allocations, with some exceptions.

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Pre-deployment Considerations for Enabling QoS in DO ATs

- What are the 1xEV-DO protocols and application capabilities of ATs?
  - Rel. 0 only protocols and Default Packet Application
  - Rev. A protocols and Multi-Flow Packet Application
  - Rev. A protocols and Enhanced Multi-Flow Packet Application
- What QoS OSI applications are supported by the AT?
  - ATs support different OSI applications based on the Make and Model of the AT like VoIP, VT, PTx, etc.
- What are the QoS requirements of the all OSI applications supported by the AT?
  - Latency, Throughput, Reliability, and Jitter

Pre-deployment Considerations for Enabling QoS DO ATs (continued)

- What QoS Flow Specification requirements of the OSI application are supported by the individual AT?
  - **FlowProfileIDs**
    - Need collaboration with the RAN.
  - Are all the flows within the application bundled to maintain application integrity?

- What QoS Filter Specification requirements of the OSI application are supported by the individual AT?
  - **Traffic Flow Templates Information Elements (TFTs IE)**
    - Need collaboration with the PDSN and AAA.

Pre-deployment Considerations for Enabling QoS in the RAN

- What are the 1xEV-DO protocols and application capabilities of the RAN?
  - **RAN may have limited support 1xEV-DO Rev. A capabilities.**

- What QoS OSI applications are supported by the RAN?
  - **RAN must be configured to identify the FlowProfileIDs requested by the AT, and:**
    - Configure the proper RLP flow characteristics.
    - Configure the proper RTCMAC Subtype 3 parameters, to ensure Reverse link OTA QoS.
    - Configure any other protocol attributes and values.

Pre-deployment Considerations for Enabling QoS in the PDSN

- What QoS Filter Specification requirements of the OSI application are supported by the operator?
  - **PDSN must be configured to identify the TFTs requested by the AT, and:**
    - Perform proper Packet Classification on both egress and ingress traffic sent and served to the ATs.
    - Perform Packet Marking for egress traffic sent by the AT.
- Perform QoS Admission Control based on feedback from the AAA.

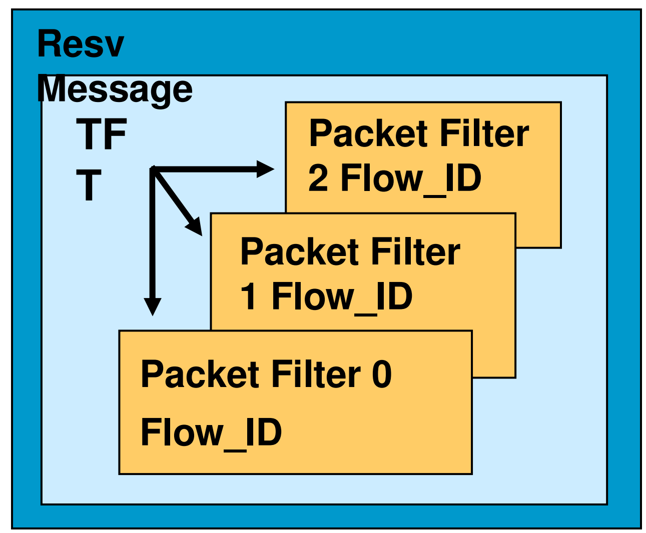
Pre-deployment Considerations for Enabling QoS in the PDSN

Traffic Flow Template

- The PDSN needs to know the
  A-10 connection (main or auxiliary) on which
  to put the
  IP packets.

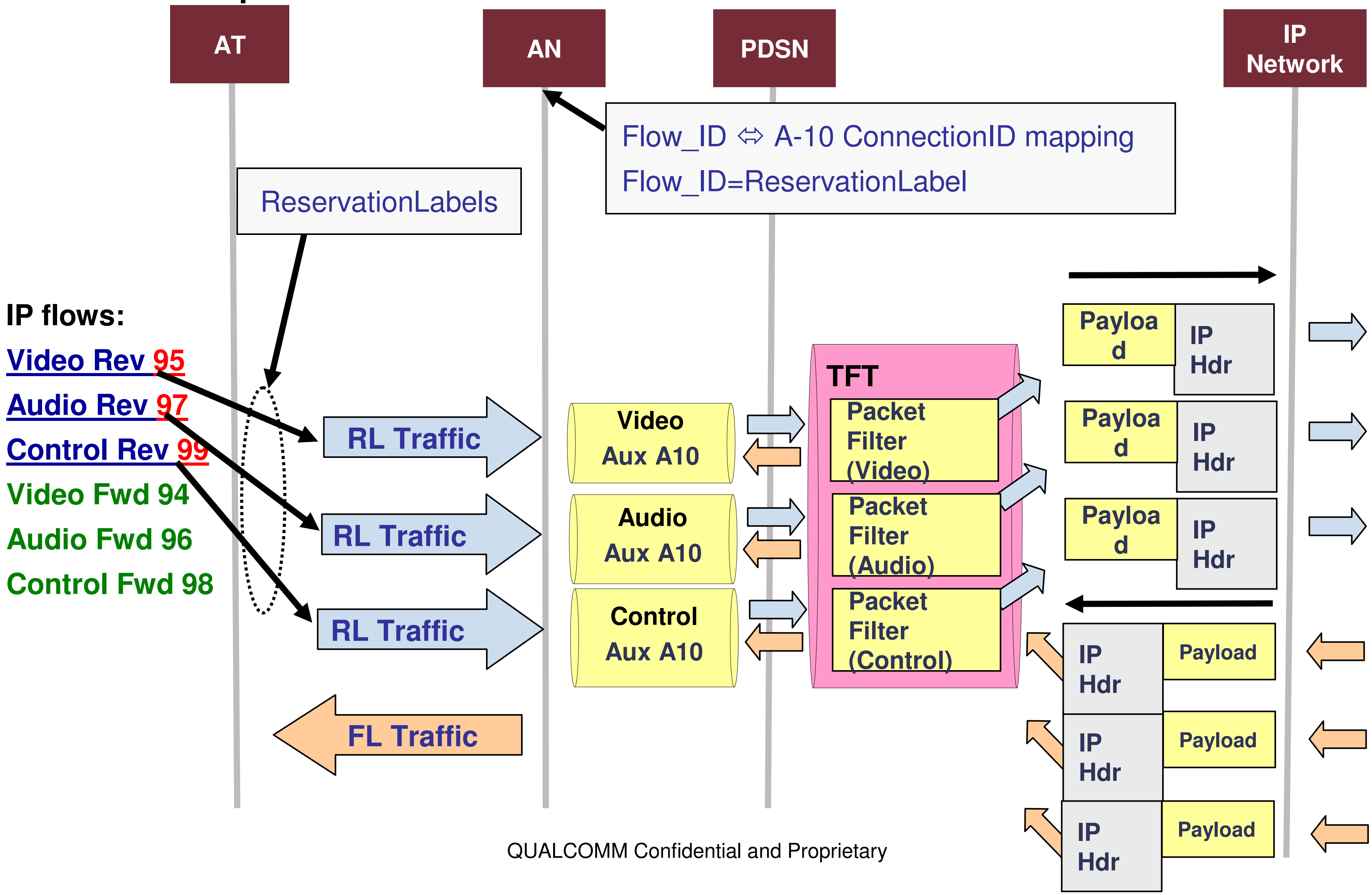
- **Traffic Flow Templates** convey:
  - A-10 to IP flow mapping information
  - QOS Parameters at the IP Layer
  - Actions to take on IP packets

- This group of information is called a **Packet Filter** .



Pre-deployment Considerations for Enabling QoS in the PDSN

TFT – Example



Pre-deployment Considerations for Enabling QoS in the Core Network

- Enable IP QoS in the:
  - Backhaul between the BTS and BSC.
  - Backbone network between the BSC and PDSN & IP international Gateway*.
    - QoS in the backhaul and backbone network maybe vendor specific proprietary implementation
      - Talk to your vendors for implementation details.
  - Core network controlled by the operator.
    - QoS in the core network can be classified based on the knowledge of all the OSI applications supported by the operator.

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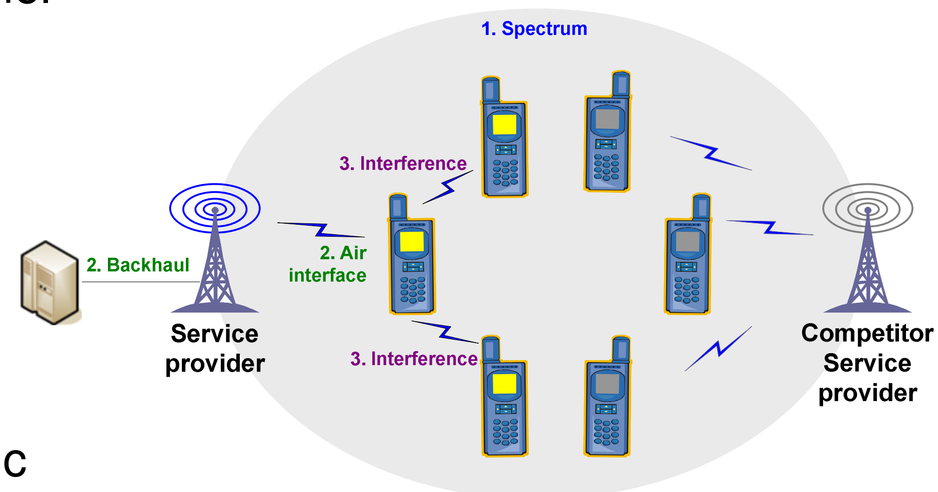
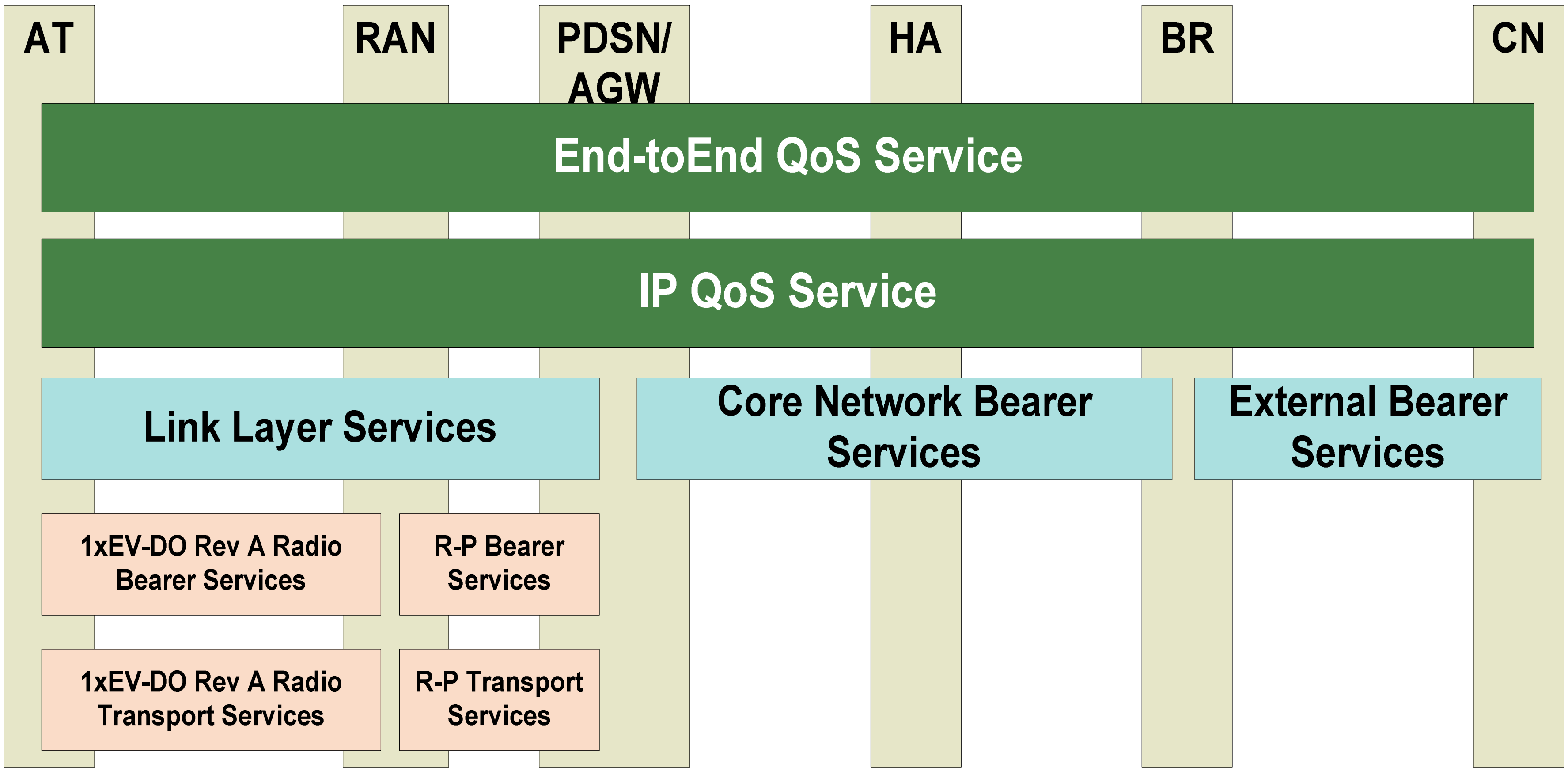
Is End-to-End QoS Necessary?

- Resource Limitations
- In the wireless world, we are resource limited:
  - Available spectrum and channel bandwidth
  - Air-interface limitations
    - Interference limitations
    - Limits system capacity
  - Battery life of mobile device
  - Backhaul limitations
    - Prioritization for QoS traffic
    - If backhaul capacity is less than air interface capacity



QoS is implemented by mechanisms and techniques to optimally control the usage of resources from the OSI Physical layer to the Application layer.

End-to-End QoS Bearer Architecture in CDMA2000 1xEV-DO Rev. A



CN: Correspondent Node (email client, website or AT)

CDMA2000 1xEVDO End to End QoS

- To Guarantee E2E QoS, operators must consider three vital segments:
  - Guarantee QoS in Access Network
  - Guarantee QoS in Core Network
  - Guarantee QoS in external IP network
- Each segment can have dissimilar QoS requirements and meet the QoS

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