QoS support in unified network architectures: challenges and a possible solution

Assistant Professor Emanuel PUŞCHIȚĂ, Ph. D.

Technical University of Cluj-Napoca
Faculty of Electronics, Telecommunication and Information Technology
Communications Department

Contents

Perspectives on QoS Resource Management

- **QoS - Quality of Service**
  - ITU-T as "the ability of a network or network portion to provide the functions related to communications between users"
  - IETF as "a set of service requirements to be met by the network while transporting a flow"
  - evaluated through the values of QoS parameters
    - delay
    - throughput
    - jitter
    - number of packets

- **QoS Resource Management Mechanisms**
  - layered QoS support

Existing QoS support mechanisms: QoS UMTS Networks

- **UMTS QoS support: 4 Traffic Classes**
  - **Conversational (CO):**
    - low delay, low jitter, symmetric traffic, no buffering (speech, VoIP, video)
  - **Streaming (ST):**
    - moderate delay, moderate jitter, asymmetric traffic, buffering allowed (video streaming, audio streaming)
  - **Interactive (IN):**
    - moderate jitter, asymmetric traffic, buffering allowed, request response pattern (web browsing)
  - **Background (BK):**
    - destination doesn’t expect data within a certain time, preserve payload content, asymmetric traffic, buffering allowed (email, file downloading)

Existing QoS support mechanisms: QoS WiMAX Networks

- **WiMAX QoS support: 5 Traffic Classes**
  - **Unsolicited Grant Service (UGS)**
    - supports delay sensitive application such as real time applications formed with fixed size of the transmitted packets
  - **Extended Real-time Polling Service (ertPS)**
    - sensitive application such as real time applications with very strict QoS requirements (i.e., Voice over IP with silence suppression)
  - **Real-Time Polling Service (rtPS)**
    - applications with less delay constraints, formed with variable size of the packets, sent at periodic intervals (i.e., video streaming)
  - **Non-real-time Polling Service (nrtPS)**
    - delay tolerant applications which require at least a minimum data transfer rate
  - **Best Effort (BE)**
    - all types of applications which have minimum or no QoS requirements, served in the best way available (i.e. web browsing).

Existing QoS support mechanisms: QoS WLAN Networks

- **WLAN QoS support: 4 Traffic Classes**
    - EDCA - Enhanced Distributed Channel Access
    - HCCA - HCF Controlled Channel Access
  - **Background (BK)**
    - non-time-critical and loss insensitive, but of lower priority than best effort
  - **Best-Effort (BE)**
    - non-time-critical and loss insensitive
  - **Video (VI)**
    - delay, jitter and packet loss sensitive
  - **Voice (VO)**
    - time critical

Perspectives on QoS Resource Management: challenges

- **Intra-domain QoS support**
  - particular QoS mechanisms – network services
    - prioritized, classified, scheduled and delivered
- **Inter-domain QoS support**
  - concern regarding the reliability of current QoS support mechanisms
    - supplementary service compatibilities must be provided
- **Unified network architectures**
    - service unification and variable network context
    - multiple terminals, access and transport networks, and operators
- **Scope**
  - to bring the perspective of an end-to-end QoS support
    - based on knowing the service requests and the network capabilities

- **Proposed solutions**:
  - clean slate / revolutionary approach
    - complete remodeling of the Internet architecture

    - **Major problems**:
      - perspective of operators/service providers on radical changes in the network
      - new legislative/normative agreements between service providers
      - difficulty in testing/evaluation/validating new architectural elements

  - pluralistic / evolutionary approach
    - gradual improvement of functionalities in the existing architecture
    - the adopted perspective

Profile-based QoS Support: a possible solution

Profile-based QoS support: a possible solution - SCOPE

- **Problem**:
  - Interconnecting multiple technologies an efficient end-to-end QoS support cannot be guaranteed
- **Existing QoS support**:
  - Designed for intra-domain QoS support
  - Delivered services - prioritized, classified, scheduled and delivered according to a particular QoS mechanisms
- **Proposed QoS Support**:
  - Designed for inter-domain QoS support
  - Based on the use of QoS Profiles
  - Determine an end-to-end QoS path
    - best accommodates specific application requirements to a particular network context

Profile-based QoS support: a possible solution - EVALUATION

- **Evaluation scenarios**:
  - The proposed QoS solution
    - implemented and evaluated through network simulations
    - validated on an experimental test-bed through network emulation
- **Evaluation metrics**:
  - QoS parameters:
    - the total number of lost packets, the mean jitter and the average end-to-end delay
- **Originality**:
  - QoS support indicates the critical parameters
  - Maps the required parameters into the specific QoS profiles
  - Selects a convenient end-to-end QoS path in the network

Profile-based QoS support: a possible solution - MODELING

- **QoS Profiles:**
  - **QoS Requested Profile:**
    - specific requirement of the source application
    - specify the critical transmission parameter (i.e., delay or jitter)
  - **QoS Path Profile:**
    - includes the best end-to-end path determined by probing the network
    - the cumulative value of the critical parameter measured on this path
  - **QoS Available Profile**:
    - uses the selected path to reach the source (from the destination)
    - marks the nodes and corresponding interfaces in order to set the end-to-end transmission path

Profile-based QoS support: a possible solution - OBSERVATIONS

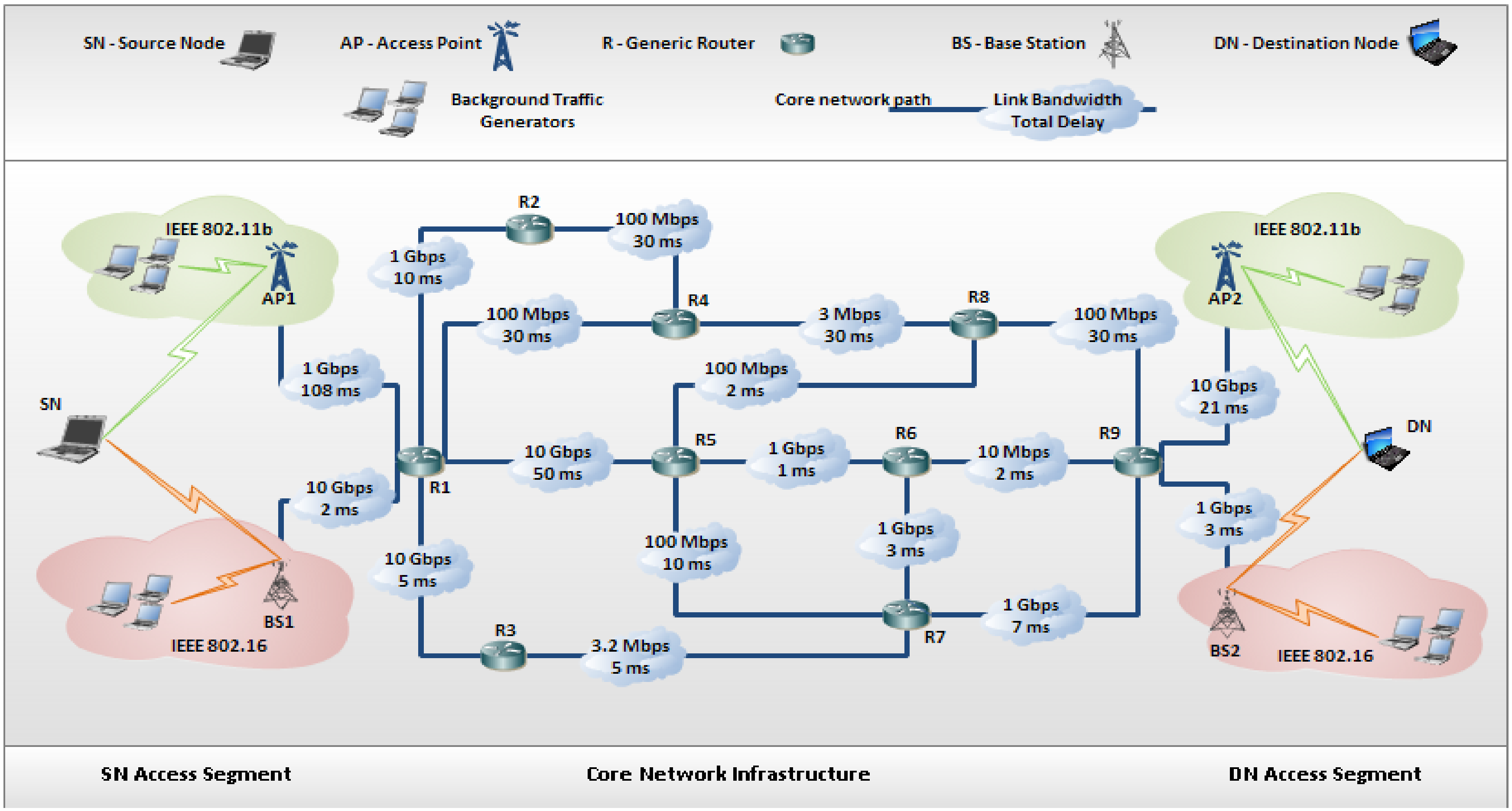
- **Notes**:
  - The mechanism avoids the routing loops
    - selects only the interface providing the best QoS Path Profile
  - Jitter and delay are cumulative values
    - the mechanism could not include the same node more than once
  - Important aspect to solve:
    - the network probing process increases the traffic
    - time to determine an end-to-end path
      - managed by controlling the number of probes in a set

Profile-based QoS Support: a possible solution

Phase 1: Evaluation through simulations

Profile-based QoS support: a possible solution - SCENARIO DESCRIPTION

- **Evaluation tool and scenario description:**



Profile-based QoS support: a possible solution - TEST APPLICATION CONFIGRATION

- **Test application:**
  - real-time applications
    - codecs transmitting equal packets at constant intervals of time
    - constant bit rate (CBR) generator

- Configuration parameters for the test application modeled by a CBR generator

Application type	Packet size (bytes)	Interval between packets (ms)	Total number of transmitted packets	Bit rate (kbps)	Duration (s)
CBR	1370	3.26	32448	3361	106

Profile-based QoS support: a possible solution - PERFORMANCE EVALUATION

- **Evaluation criteria**:
  - Compare proposed QoS support performances with the ones of the existing QoS network support
    - best-effort (BE) and priority based traffic conditions
      - IP Precedence field to 5 (Network Layer)

- **Performances of the existing QoS support for the test application:**

BE	Routing protocol	OSPFv2	RIP	Bellman Ford
	End-to-end path	SN-AP1-R1-R4-R8-R9-AP2-DN		
	Average end-to-end delay (ms)	718.58	718.58	713.54
	Average jitter (ms)	1.60	1.60	1.63
	Packet loss (%)	29.24	29.24	29.31
IP Precedence = 5	Routing protocol	OSPFv2	RIP	Bellman Ford
	End-to-end path	SN-AP1-R1-R4-R8-R9-AP2-DN		
	Average end-to-end delay (ms)	624.45	624.45	624.41
	Average jitter (ms)	1.34	1.34	1.34
	Packet loss (%)	14.44	14.44	14.44

Profile-based QoS support: a possible solution - OBSERVATIONS

- **Notes:**
  - Same path regardless of the used routing protocol
    - no correlation between the application requirements and the network selected path
  - The average end-to-end delay and the packet loss exceed the maximal accepted values
    - existing network mechanisms cannot offer an appropriate QoS support for the test application

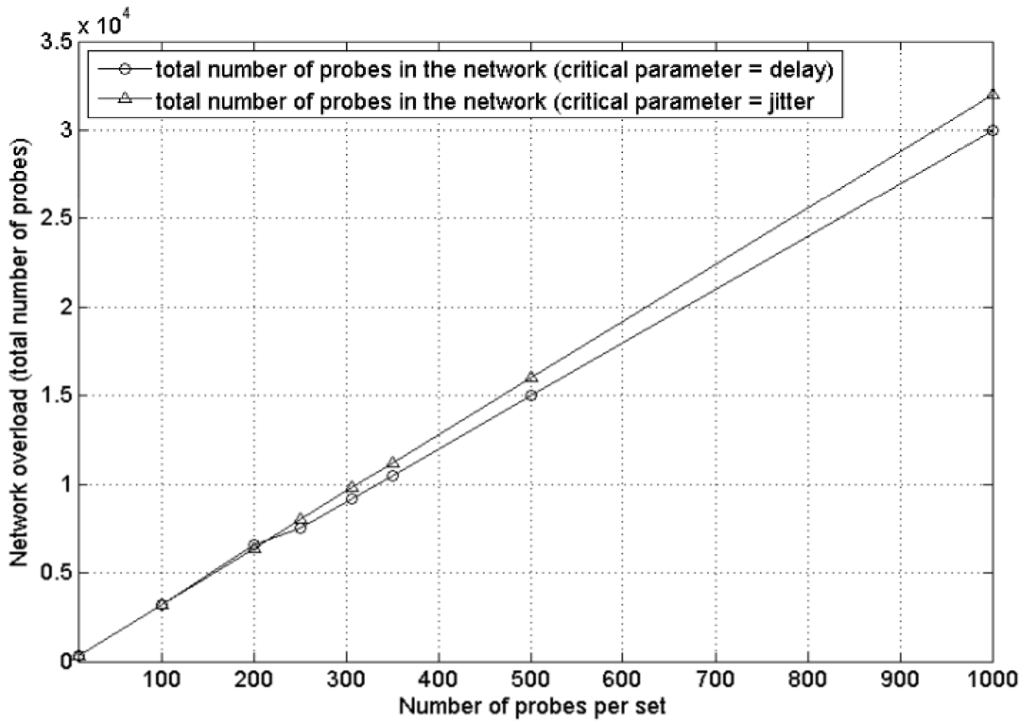
<u>Profile-based QoS support: a possible solution - PERFORMANCE EVALUATION</u>

- **<u>Performances of the profile-based QoS support for the test application</u>:**
  - a patch application and integrated in QualNet Developer 5.1
  - probing the network
    - to identify a convenient end-to-end path according to the application requirements
    - considering application critical parameters
  - the number of probes in a set determines
    - the network overload
    - the path estimation time

- **<u>The question</u>: Which is the appropriate number of probes in a set?**

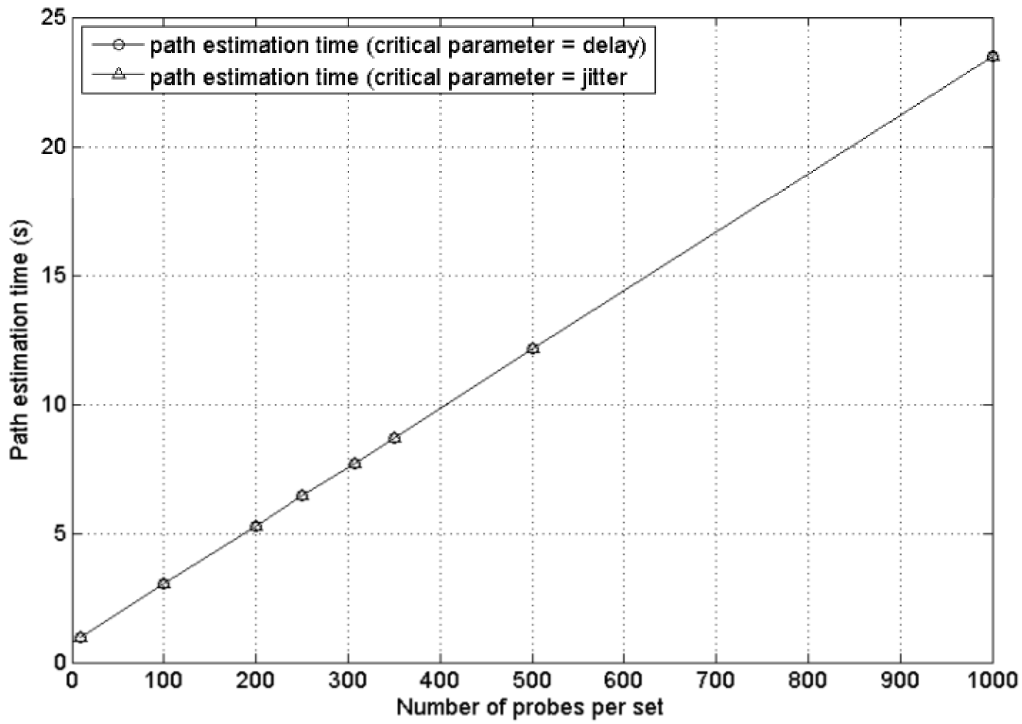
Profile-based QoS support: a possible solution - THE NUMBER OF PROBES IN A SET

- **Probing the network:**
  - **The network overload** when the critical parameter is set to delay or jitter



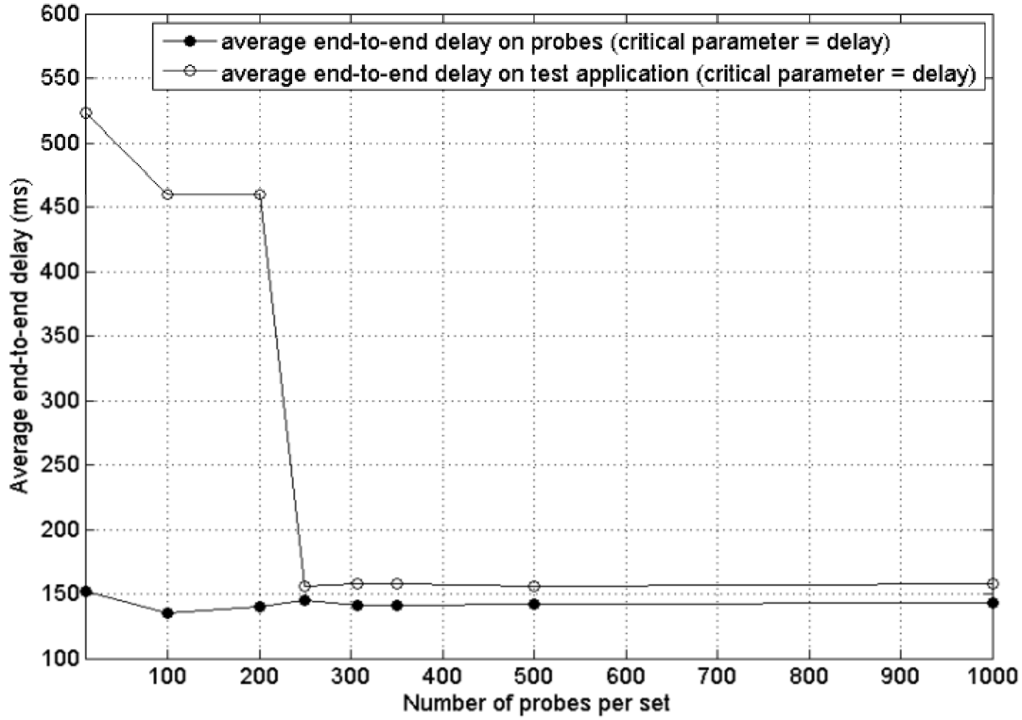
Profile-based QoS support: a possible solution - THE NUMBER OF PROBES IN A SET

- **Probing the network:**
  - **The path estimation time** when the critical parameter is set to delay or jitter



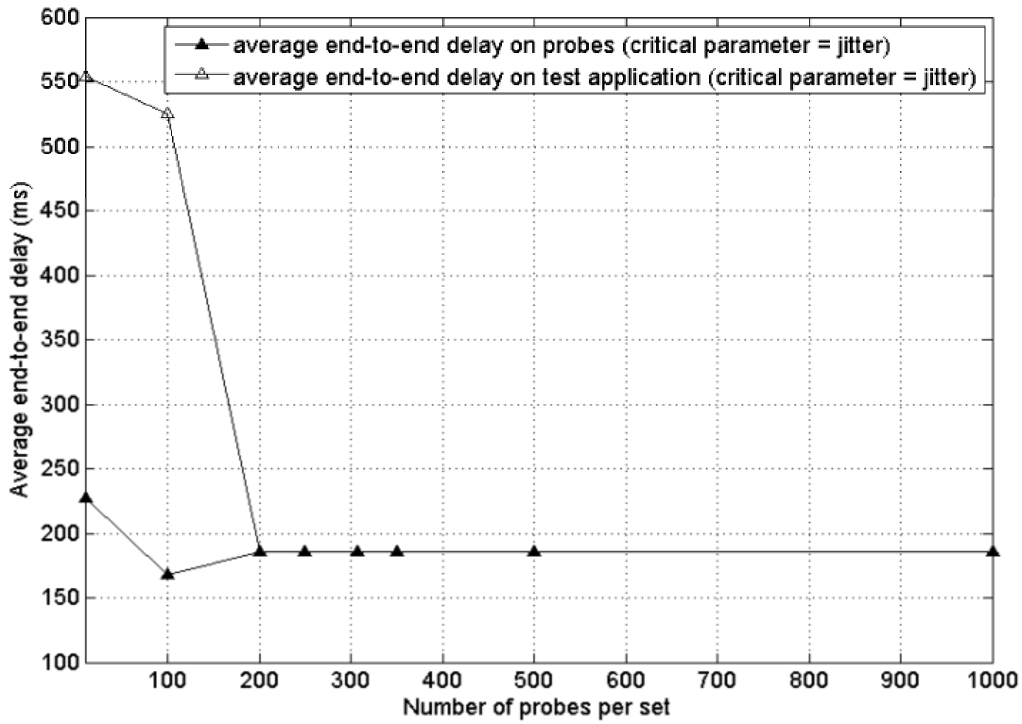
Profile-based QoS support: a possible solution - THE NUMBER OF PROBES IN A SET

- **Comparative representation:**
  - the **average end-to-end delay** on probes and the average end-to-end delay on test application when the critical parameter is set to **delay**



Profile-based QoS support: a possible solution - THE NUMBER OF PROBES IN A SET

- **Comparative representation:**
  - the **average end-to-end delay** on probes and the average end-to-end delay on test application when the critical parameter is set to **jitter**

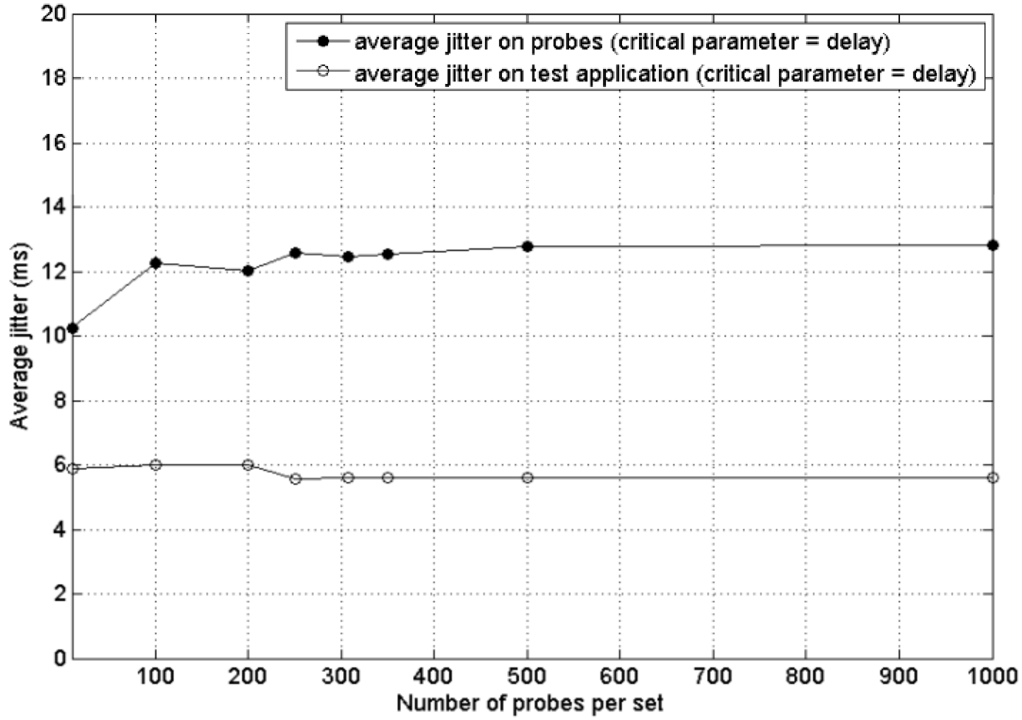


Profile-based QoS support: a possible solution - OBSERVATIONS

- **Notes:**
  - For a reduced number of probes in a set
    - the **average end-to-end delay** estimated on probes does not accurately predict the behavior of the test application
  - Increasing the number of probes per set
    - improvement of the prediction
    - from a certain point the probing process generates only additional network traffic

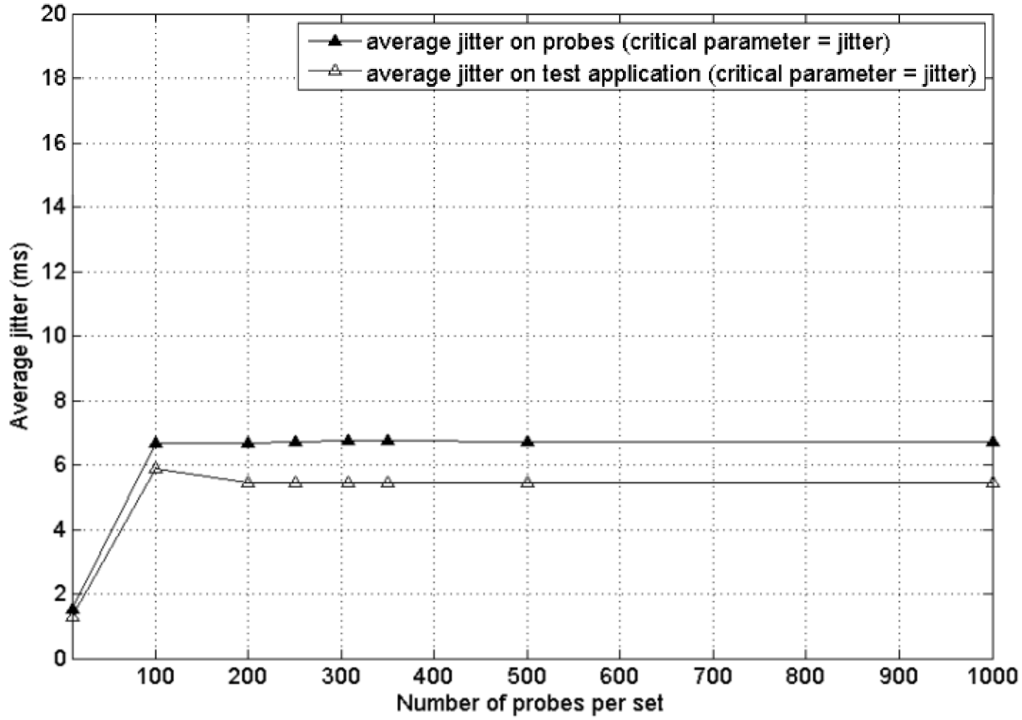
Profile-based QoS support: a possible solution - THE NUMBER OF PROBES IN A SET

- **Comparative representation:**
  - the **average jitter** on probes and the average jitter on test application when the critical parameter is set to **delay**



Profile-based QoS support: a possible solution - THE NUMBER OF PROBES IN A SET

- **Comparative representation:**
  - the **average jitter** on probes and the average jitter on test application when the critical parameter is set to **jitter**



Profile-based QoS support: a possible solution - OBSERVATIONS

- **Notes**:
  - A reduced number of probes in a set
    - apparently better predicts the behavior of the test application
    - the corresponding end-to-end selected paths the transmission experiences an important packet loss (see Table in next slide)
  - A large number of probes per set
    - determine alternative network paths
    - similar average jitter values but with no packet losses

Profile-based QoS support: a possible solution - SIMULATION RESULTS

- **Selected paths and packet loss for different sets of probes:**

<table>
<tr><td rowspan="3">Critical parameter = delay</td><td>Number of probes in a set</td><td>10</td><td>100</td><td>200</td><td>300</td><td>500</td><td>1000</td></tr>
<tr><td>Selected end-to-end path (hop number)</td><td>SN-AP1-R1-R3-R7-R6-R9-BS2-DN</td><td>SN-BS1-R1-R3-R7-R6-R9-BS2-DN</td><td>SN-BS1-R1-R3-R7-R6-R9-BS2-DN</td><td colspan="3">SN-BS1-R1-R5-R6-R9-BS2-DN</td></tr>
<tr><td>Packet loss (%)</td><td>8.99</td><td>9.11</td><td>9.10</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td rowspan="3">Critical parameter = jitter</td><td>Number of probes in a set</td><td>10</td><td>100</td><td>200</td><td>300</td><td>500</td><td>1000</td></tr>
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<tr><td>Packet loss (%)</td><td>9.17</td><td>8.99</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Profile-based QoS support: a possible solution - OBSERVATIONS

- **Notes:**
    - The end-to-end path changes with the number of probes per set
    - A reduced number of probes
        - do not accurately predict the behavior of the test application
            - the average end-to-end delay prediction is too optimistic
            - there are packet losses on these indicated paths
    - A large number of probes per set
        - the path estimation time and network loading are not feasible
            - determined path remains the same and no packet loss occurs

Profile-based QoS support: a possible solution - THE NUMBER OF PROBES IN A SET

- **The question : Which is the appropriate number of probes in a set?**
- **The role of the probes in a set:**
  - number of probes per set should guarantees
    - the selection of the end-to-end path
    - best average delay or jitter estimation
    - no packet loss
- **The answer …**
  - given by the test application packet rate

$$[\text{Number of probes in a set}] = \frac{1}{\text{Interval between packets (s)}}$$

Profile-based QoS support: a possible solution - SIMULATION RESULTS

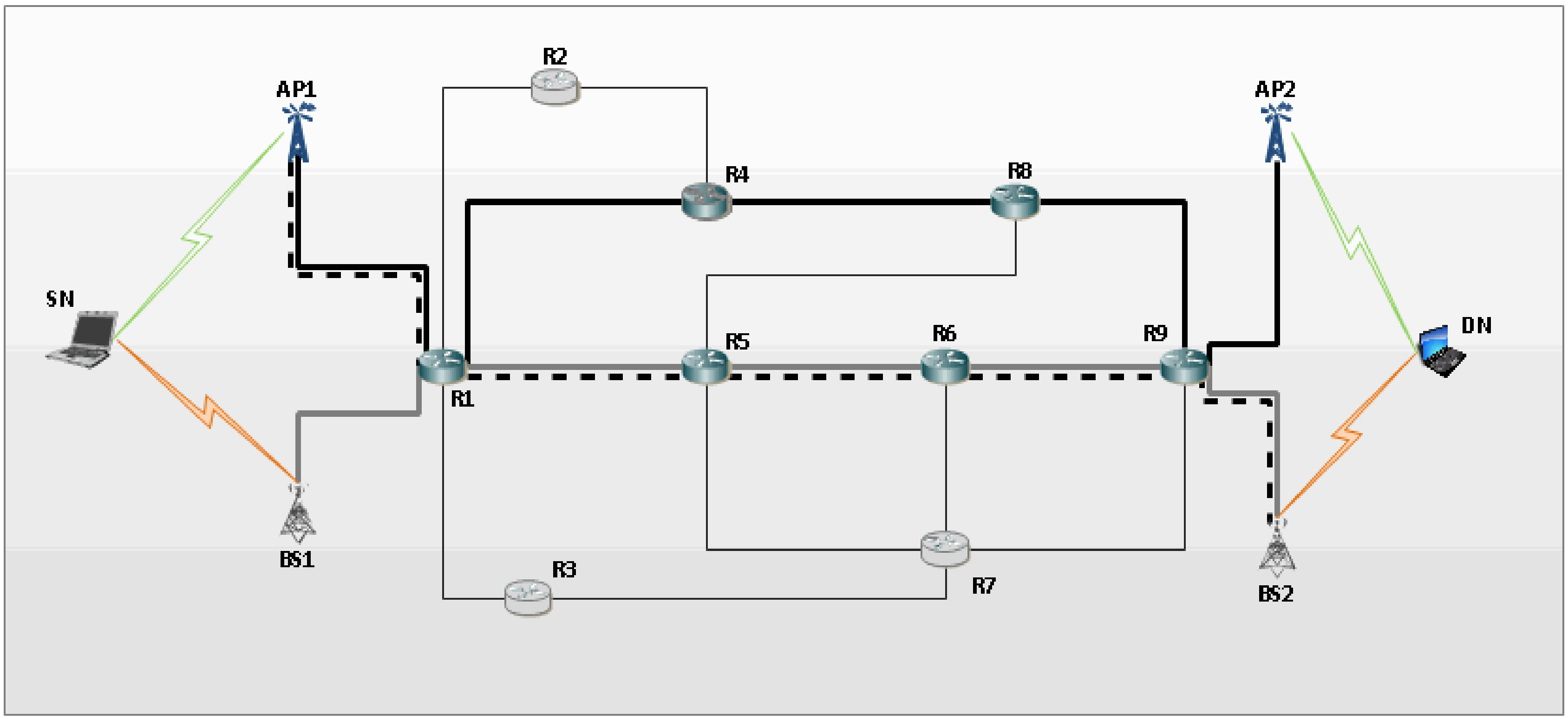
- **Performances of the profile-based QoS support for the test application:**

Existing QoS support IP Precedence =5	End-to-end path	SN-**AP1**-R1-R4-R8-R9-**AP2**-DN
	Average end-to-end delay (ms)	624.45
	Average jitter (ms)	1.34
	Packet loss (%)	14.44
Proposed QoS support Critical parameter = delay	End-to-end path	SN-**BS1**-R1-**R5**-**R6**-R9-**BS2**-DN
	Average end-to-end delay (ms)	158.41
	Average jitter (ms)	5.60
	Packet loss (%)	0
Proposed QoS support Critical parameter = jitter	End-to-end path	SN-**AP1**-R1-R5-R6-R9-**BS2**-DN
	Average end-to-end delay (ms)	185.69
	Average jitter (ms)	5.45
	Packet loss (%)	0

- The end-to-end path changes with the **critical_parameter**

Profile-based QoS support: a possible solution - NETWORK PATHS

- **Selected end-to-end network paths:**
  - existing QoS support (solid black line); critical_parameter = delay (solid gray line); critical_parameter = jitter (dashed black line)

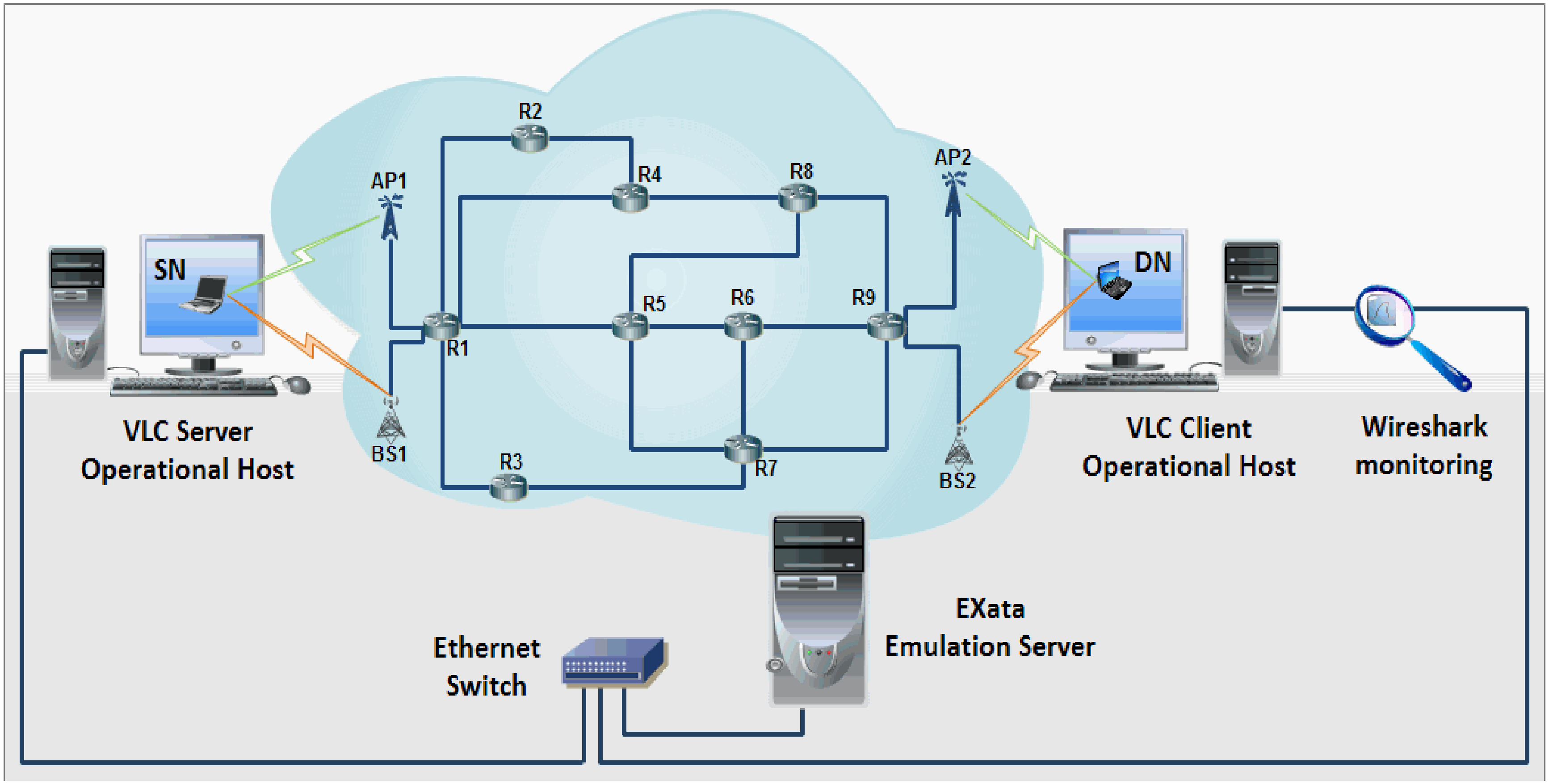


Profile-based QoS Support: a possible solution

Phase 2: Validation trough emulation

Profile-based QoS support: a possible solution – EXPERIMENTAL SETUP

- **Laboratory test-bed**:
  - real network in real-time using real applications (EXata, VLC and Wireshark)



Profile-based QoS support: a possible solution - TEST APPLICATION CONFIGRATION

- **Test application**:
  - VLC media player
    - replace the CBR traffic generator

- settings of the video test file running on the VLC server
  - CBR test application (simulation) ⇔characteristics of the video streaming (emulation)
  - total number of sent packets, packet size and sequence duration – the same for both test application and video stream

Application type	Container	Resolution (pixels)	File size (MB)	Frame rate (fps)	Bit rate (kbps)	Duration (s)
Video	AVI	1280x544	39.2	23.976	3094	106

Profile-based QoS support: a possible solution - PERFORMANCE EVALUATION

- **Evaluation metrics**:
  - Wireshark
    - total number of transmitted packets
    - packet loss
    - mean jitter
  - average end-to-end delay - not measured
    - the clocks of the two operational hosts were not synchronized with the EXata emulation server
- **Evaluation analysis**:
  - Compare the existing QoS support and the proposed QoS support
    - critical parameters = delay and jitter

Profile-based QoS support: a possible solution - EXPERIMENTAL RESULTS

- **Video streaming performances on the experimental test-bed:**

	Existing QoS Support	Critical parameter = delay	Critical parameter = jitter
Total number of sent packets	32448		
Packet size (bytes)	1370		
Selected end-to-end path (hop number)	SN-AP1-R1-R4-R8-R9-AP2-DN	SN-BS1-R1-R5-R6-R9-BS2-DN	SN-AP1-R1-R5-R6-R9-BS2-DN
Packet loss ratio (%)	55.69	12.26	11.6
Mean jitter (ms)	4.77	6.30	5.73

Profile-based QoS support: a possible solution - OBSERVATIONS

- **Notes:**
  - EXata real network interfaces
    - larger packet loss and mean jitter than the ones obtained in the simulations
  - Profile-based QoS support
    - offers the best performances even for the real video transmission
    - selects an end-to-end path that meets the application requirements considering its critical parameter

- **Problem: experimental results indicate unacceptable packet loss!**
- **Solution: application reconfiguration**

Profile-based QoS Support: a possible solution

Phase 3: Reconfiguration of the test application

Profile-based QoS support: a possible solution - APPLICATION RECONFIGURATION

- **Test application parameters**:
  - reconfigured parameters for the test application
  - decrease the CBR traffic generator bit rate
    - the interval between packets was increased

Application type	Packet size (bytes)	Interval between packets (ms)	Total number of transmitted packets	Bit rate (kbps)	Duration (s)
CBR	1370	6.09	17385	17975	106

- **Notes**:
  - **Network probing**: total number of probes per set is 165
  - **Scope**: to reduce the packet loss

Profile-based QoS support: a possible solution - APPLICATION RECONFIGURATION

- **Simulation results - existing QoS support:**

BE	Routing protocol	OSPFv2	RIP	Bellman Ford
	End-to-end path (hop number)	SN-AP1-R1-R4-R8-R9-AP2-DN		
	Average end-to-end delay (ms)	704.17	704.17	704.51
	Average jitter (ms)	2.67	2.67	2.72
	Packet loss (%)	15.31	15.31	15.61
IP Precedence =5	Routing protocol	OSPFv2	RIP	Bellman Ford
	End-to-end path (hop number)	SN-AP1-R1-R4-R8-R9-AP2-DN		
	Average end-to-end delay (ms)	227.85	227.85	227.9
	Average jitter (ms)	2.04	2.04	2.04
	Packet loss (%)	0	0	0

- average end-to-end delay and the packet loss were reduced
- selected end-to-end path remains the same regardless of the changes
- existing QoS support is insensitive to the application characteristics

Profile-based QoS support: a possible solution - APPLICATION RECONFIGURATION

- **Simulation results - proposed QoS support:**

	Critical parameter = delay	Critical parameter = jitter
Number of probes per set	165	
Total number of probes in the network	5280	
Path estimation time (s)	7.67	
Selected end-to-end path (hop number)	SN-**BS1**-R1-R3-R7-**R6**-R9-BS2-DN	SN-**AP1**-R1-R3-R7-R9-BS2-DN
Average end-to-end delay (ms)	122.64	152.13
Average jitter (ms)	9.2	8.46
Packet loss (%)	0	0

- new end-to-end paths selected imposed by the **critical_parameter**
  - low average end-to-end delay
  - no packet loss

Profile-based QoS support: a possible solution - APPLICATION RECONFIGURATION

- **Video application parameters on the experimental test-bed**:
  - transrated the video test application

Application type	Container	Resolution (pixels)	File size (MB)	Frame rate (fps)	Bit rate (kbps)	Duration (s)
Video	AVI	1280x544	20.7	23.976	1633	106

Profile-based QoS support: a possible solution - APPLICATION RECONFIGURATION

- **Experimental results:**

	Existing QoS Support	Critical parameter = delay	Critical parameter = jitter
Total number of sent packets	17385		
Packet size (bytes)	1370		
Selected end-to-end path (hop number)	SN-AP1-R1-R4-R8-R9-AP2-DN	SN-BS1-R1-R3-R7-R6-R9-BS2-DN	SN-AP1-R1-R3-R7-R9-BS2-DN
Packet loss ratio (%)	36.12	8.25	8.02
Mean jitter (ms)	5.85	9.64	8.23

- profile-based QoS support provides considerable improvements in terms of packet loss

Conclusions

- **Propose a profile-based QoS support**
  - Scope: to improves the resource management in a scenario unifying different network technologies
  - Design: developed as a patch application
  - Performances: evaluated through simulation and validated trough emulation on a laboratory network platform
  - Specific elements: QoS profiles, set of probes, critical parameters
  - Results: better performances in terms of average end-to-end delay and number of lost packets
- Simulation tool: QualNet Developer 5.1
- Emulation platform: EXata 2.2

Limitations and discussions

- The probes are used to perform measurements and network monitoring
  - the probing process is triggered only once before running the application
  - periodic probing is needed
- An adaptation process at the application level would improve the performances
  - decreasing the application bit rate proved to be a possible solution
- Path selection based only on the evaluation of one critical parameter
  - a comprehensive decision requires a composite metric

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Emanuel PUSCHITA

Emanuel.Puschita@com.utcluj.ro
Faculty of Electronics, Communications and Information Technology