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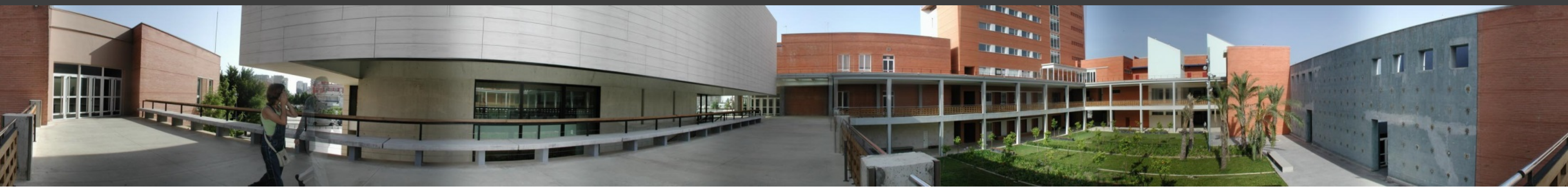
CAMPUS DE GANDIA

IGIC
Instituto de investigación para la gestión integrada de zonas costeras



Multimedia delivery Using Artificial Intelligence over SDN

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NexComm 2019

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Head of the Innovation Group EITACURTE

Internet Technical Committee Chair (term 2014-2015)

Chair of the IEEE 1907.1 Standard

Co-editor-in-Chief of Ad Hoc and Sensor Wireless Networks (JCR: 0.753, TELECOMMUNICATIONS)

Advisory Board of International Journal of Distributed Sensor Networks (JCR: 1.787, TELECOMMUNICATIONS)

Associate Editor-in-Chief of Sensors, Sensor Networks Section (JCR: 2.475, INSTRUMENTS AND INSTRUMENTATION)

Editor-in-Chief of the International Journal "Network Protocols and Algorithms"

Editor-in-Chief of International Journal of Multimedia Communications

IARIA Journals Board Chair (8 Journals)

Chair of: 18th ICN 2019, 14th ICDT 2019, 12th CTRQ 2019, 4th FMEC 2019, GC-ElecEng 2019 and 10th ISAmI

Publications:

http://scholar.google.com/citations?user=ZJYUEGEAAAAJ

https://www.researchgate.net/profile/Jaime_Lloret2/publications/

http://www.informatik.uni-trier.de/~ley/pers/hd/m/Mauri:Jaime_Lloret

http://www.scopus.com/authid/detail.url?authorId=23389476400

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Introduction - University

Polytechnic University of Valencia (UPV) is a public educational institution (3 campus sites with more than 36,000 students, almost 3,000 members of teaching and research staff, and about 2,400 administrative and services staff).

UPV combines training with research and encouraging investigation and projects, balancing theoretical and applied research.

It has 41 departments, 40 research centres and institutes, 4,055 people involved in research structures, 410 skills, 222 patents, 13 results, 41 software, and offering 56 Master's degrees and 28 Doctor's degrees.

UPV is composed of 11 schools, 2 faculties and 2 higher polytechnic schools.

Introduction - University

Quality Metrics:

UPV is in the top 310 best universities of the world, according to the QS World University Rankings, and it is in the position 155 in the international patents.
http://www.upv.es/noticias-upv/noticia-10133-qs-world-unive-es.html

UPV is the best technical university in Spain, according to Shangay University Rankings (it is in the best 400 universities of the world)
http://www.upv.es/noticias-upv/noticia-6802-ranking-de-shan-es.html

Times Higher Education (THE*) Young University Rankings recognizes UPV in the first 150 universities of the world*.
http://www.upv.es/noticias-upv/noticia-10152-the-young-univ-es.html

Introduction – Research Institute

The **Integrated Management Coastal Research Institute (IGIC)** belongs to the UPV.

http://cienciagandia.webs.upv.es/2015/01/el-instituto-de-investigacion-igic-situa-al-campus-de-gandia-como-referente-internacional/
https://www.upv.es/entidades/IGIC/indexi.html

IGIC's general aim is to promote and conduct scientific research of excellence on various aspects of integrated coastal zone management.

The research of the institute is structured into three main areas:

(1) Environmental study and conservation of biological resources in coastal zones;
(2) Technological tools applied to marine and coastal environments;
(3) Coastal zone planning and management.

It is a multidisciplinary Institute with 70 researchers from different areas.

Outline

- State of the art
- Multimedia delivery Using Artificial Intelligence over SDN
- Performance Tests

State of the art

State of the Art

Current networks have much limitation due to their rigidity, which is given by static configurations mainly based on commands or static scripts.

The resource provisioning is less automatic and the efficiency decreases.

Moreover, virtualization and cloud are changing radically the traffic patterns of the data center.

This is mainly due to the communication between servers, because the applications are split in many virtual machines that must communicate.

State of the Art

Software Defined Networks (SDNs) are able to divide the control plane from the data plane, which allow higher programmable, automatic and flexible networks.

In SDNs, we do not need to program node by node, but by a centralized manner through software that can be implemented independently of the manufacturer or the model.

SDNs provide a more open network and allow accessing better to certain intelligent functions, which can contribute higher intelligence to the network operating.

These features make SDNs ideal to have a system that is able to adapt with the aim of having higher performance.

State of the Art

Information gathered from the network can be used to implement a series of procedures:

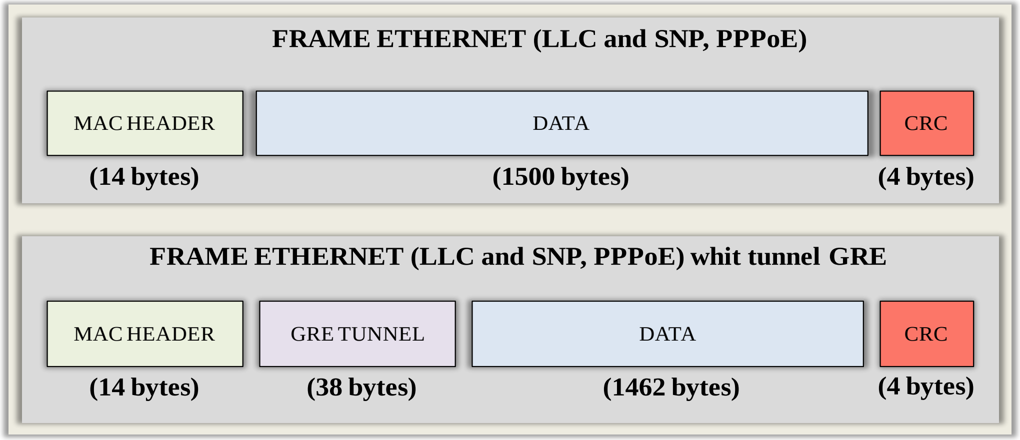
- Observing traffic patterns for different network devices or the used protocols
- The behavior of the users and servers
- The additional information that can be taken from the wireless networks (user movement, location, etc.).

Artificial intelligence and automatic learning can be used over the available information.

This will allow improving a specific objective and achieve higher system performance.

State of the Art

Previous tests on SDN:



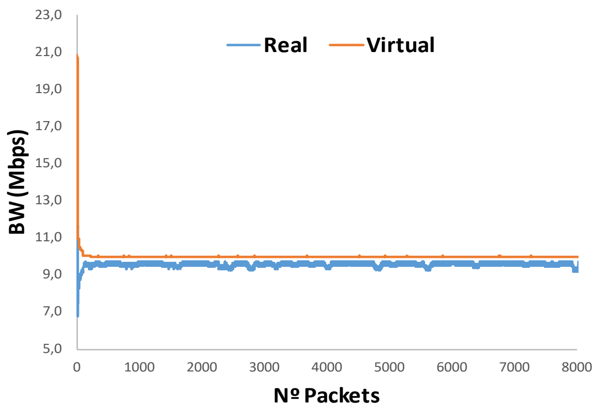
Test bandwidth and jitter using three different MTUs:

1518 (Ethernet), 4370 (FDDI) and 7999 (WLAN 802.11).

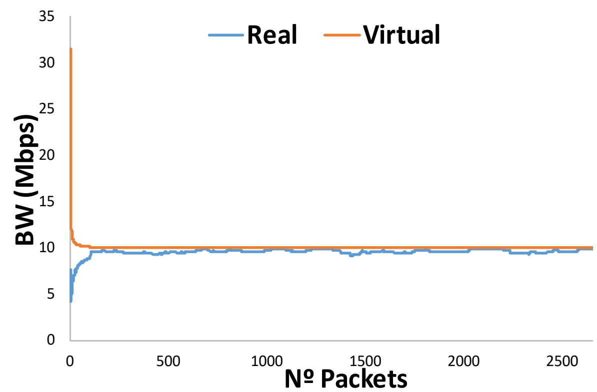
State of the Art

Previous tests on SDN (data):

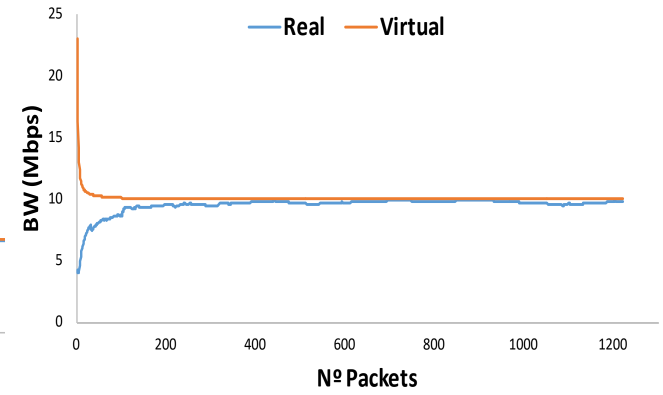
MTU: 1518

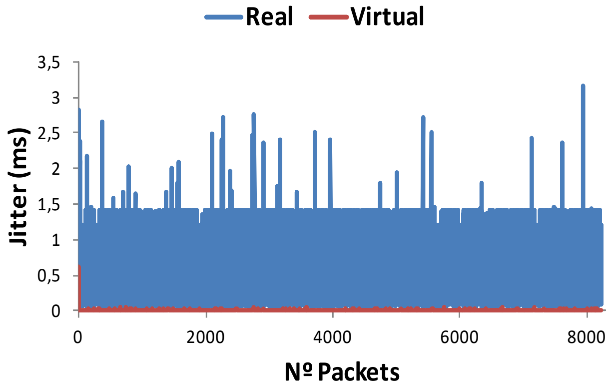


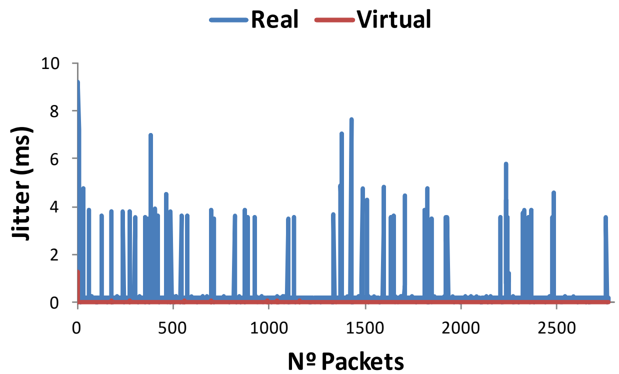
MTU: 4370

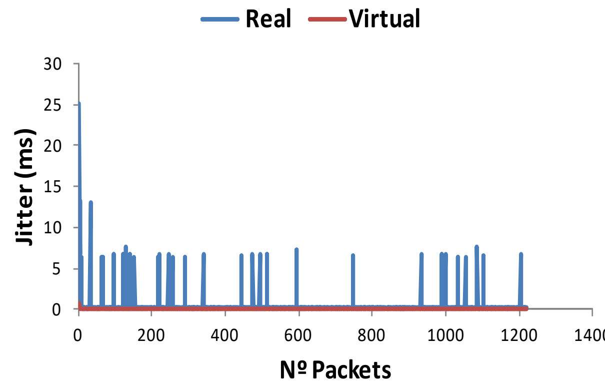


MTU: 7999









Traffic links bandwidth 10 Mbps

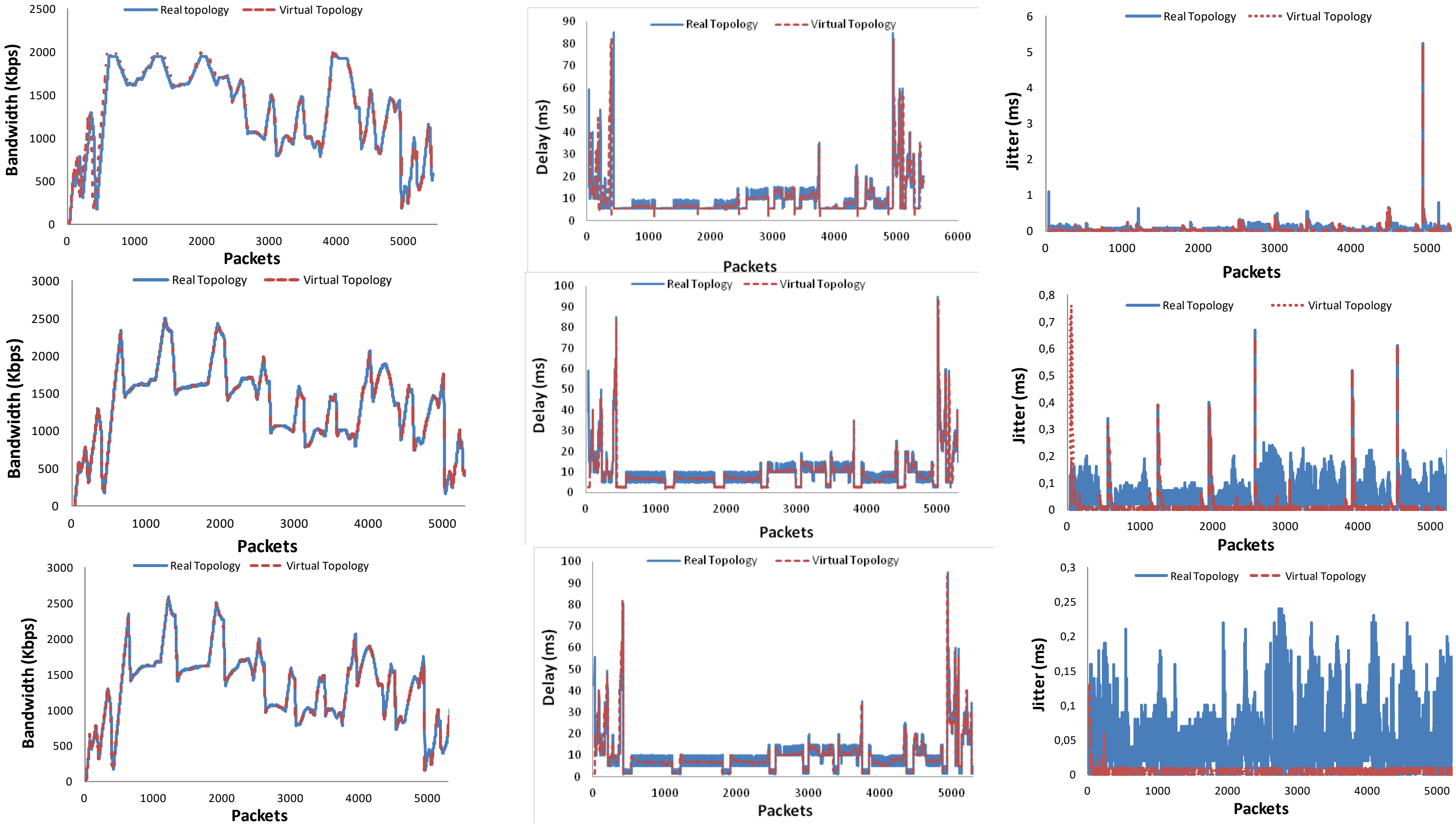
State of the Art

Previous tests on SDN (multimedia):

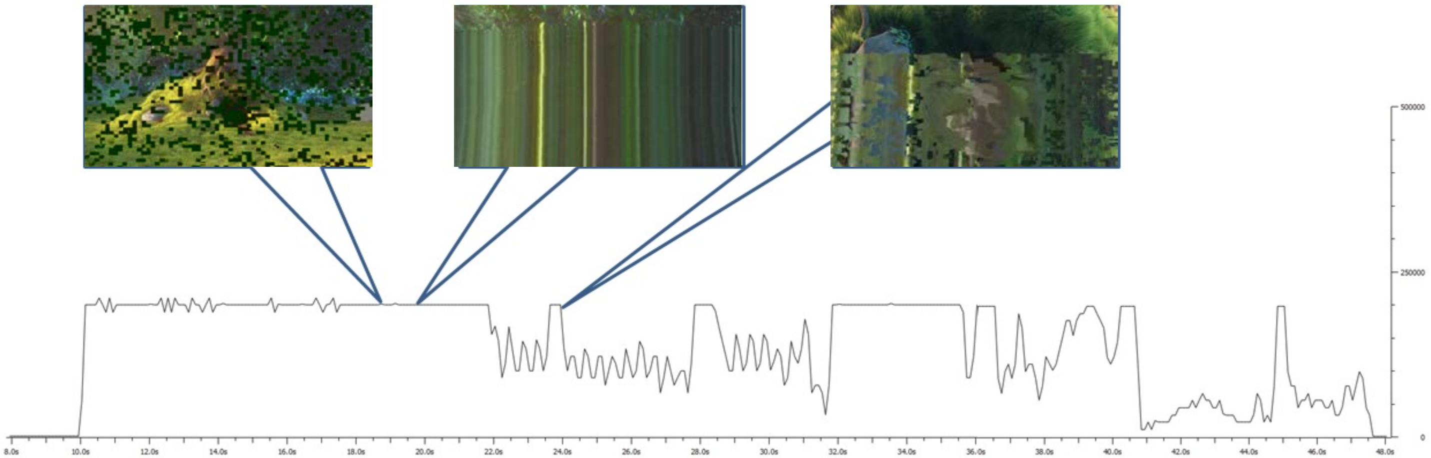
2Mbps

4Mbps

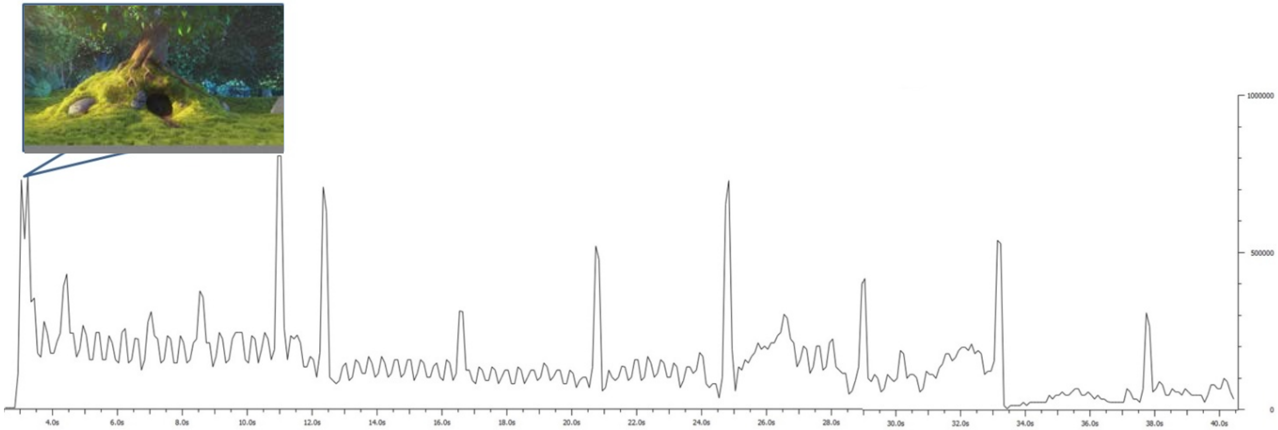
8Mbps



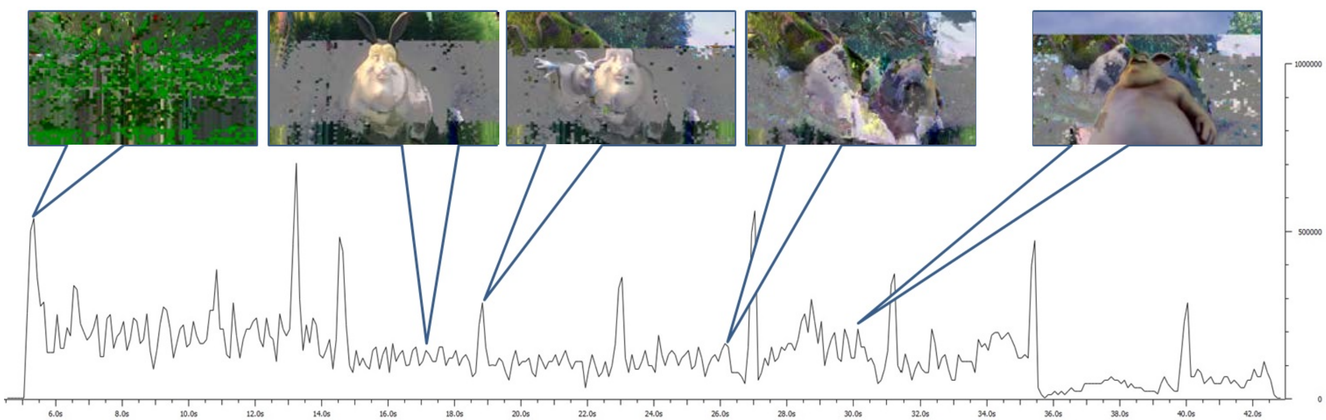
Previous tests on Multimedia Delivery:



Real case when bandwidth is 2Mbs



AP 1 mW - 10 Mbps



AP 1 mW - 12 Mbps

Multimedia delivery Using Artificial Intelligence over SDN

Features of Intelligent Systems for Multimedia Delivery:

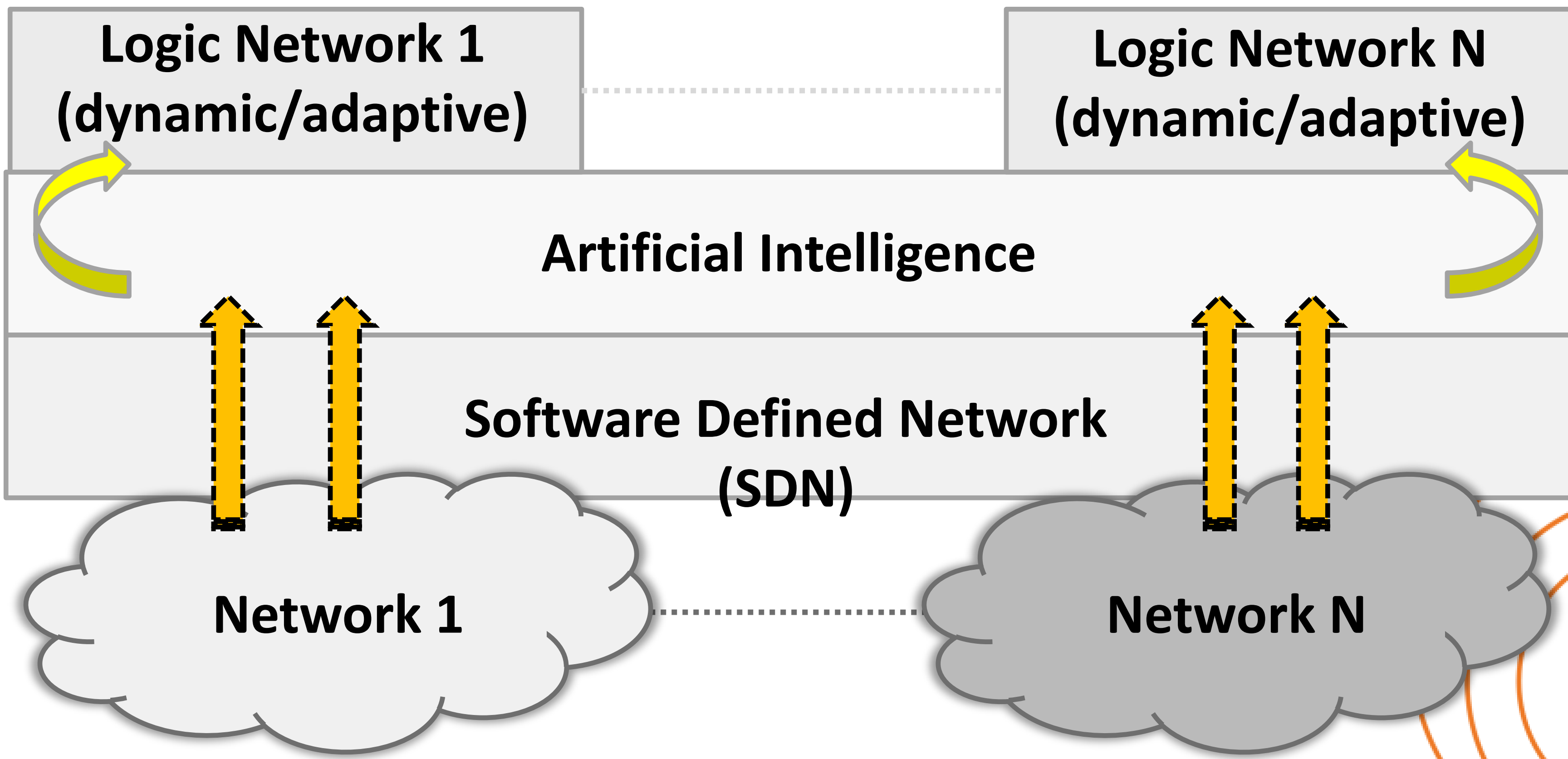
They must have an efficient network architecture and communication protocol design

They use the information taken from the data frames, the users and servers behavior, and the traffic patterns (traffic changes, quality of service parameters, state of the frames, etc.) with the aim of improving the multimedia delivery performance, by self adapting in each case.

The network infrastructure has several network devices that gather information from the network.

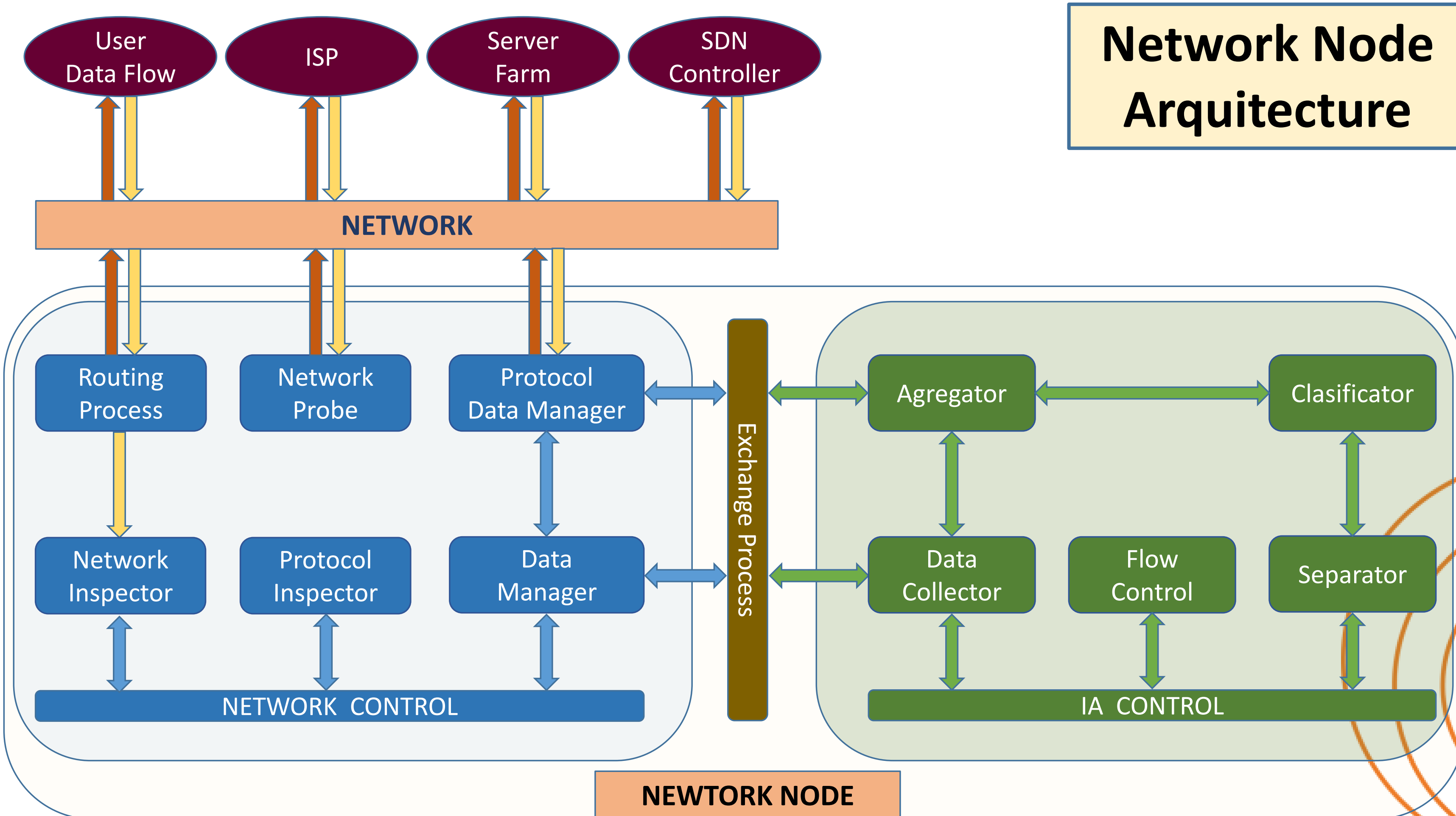
This information is used to estimate some network parameters and patterns that are used by a smart network algorithm to evolve behaviors based on this empirical data.

Multimedia delivery Using Artificial Intelligence over SDN

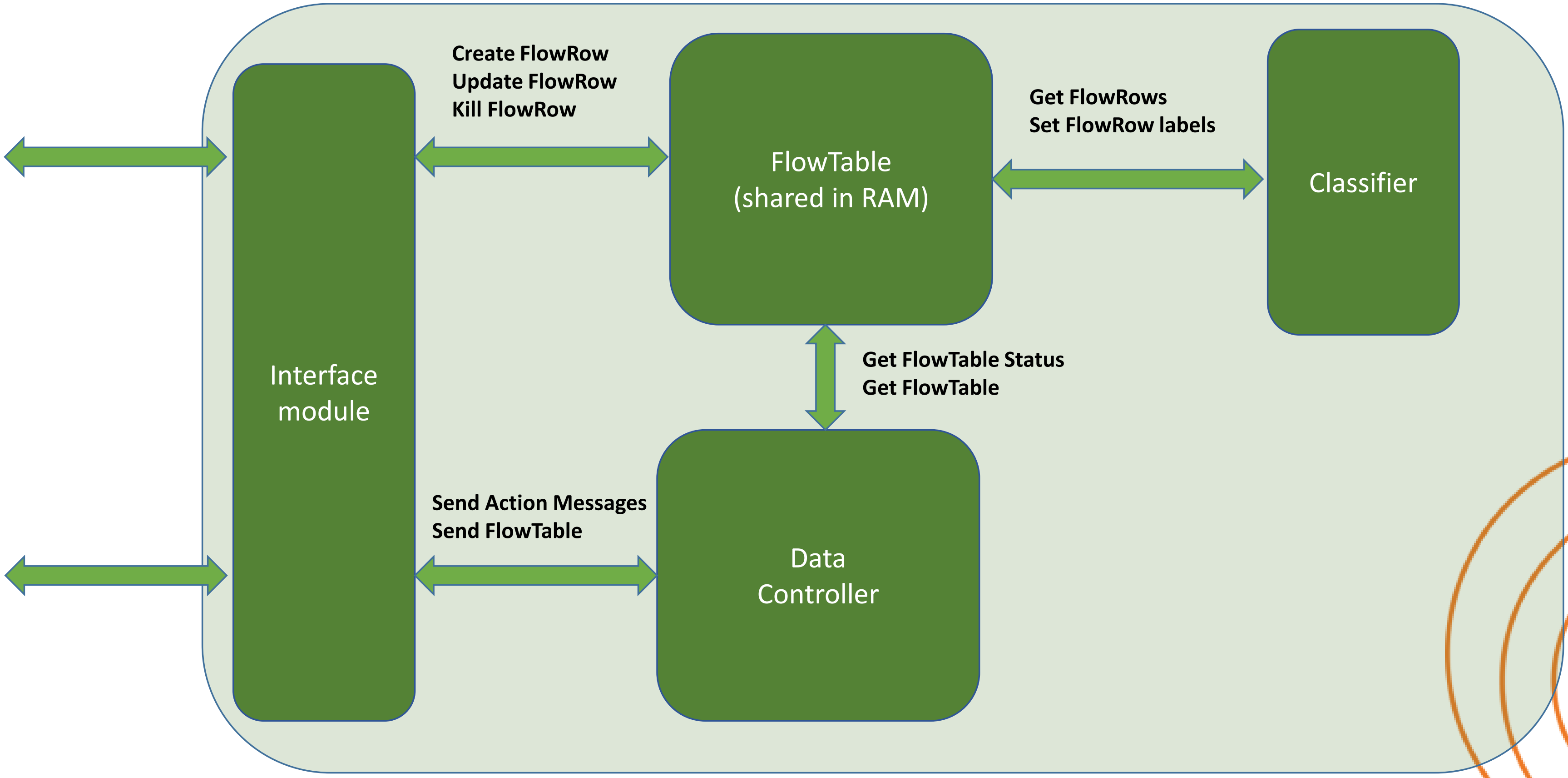


Multimedia delivery Using Artificial Intelligence over SDN

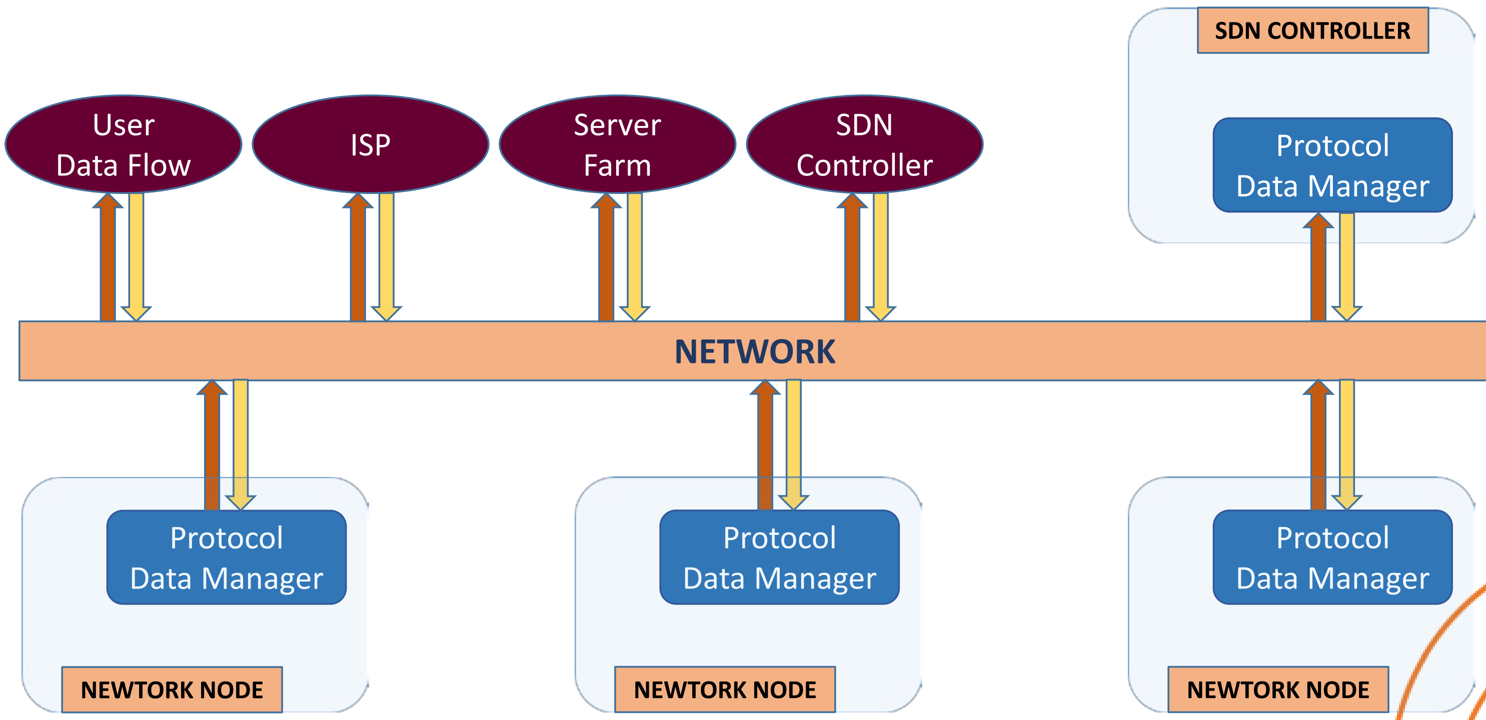
Network Node Arquitecture



Multimedia delivery Using Artificial Intelligence over SDN



Multimedia delivery Using Artificial Intelligence over SDN



Network Arquitecture

Multimedia delivery Using Artificial Intelligence over SDN

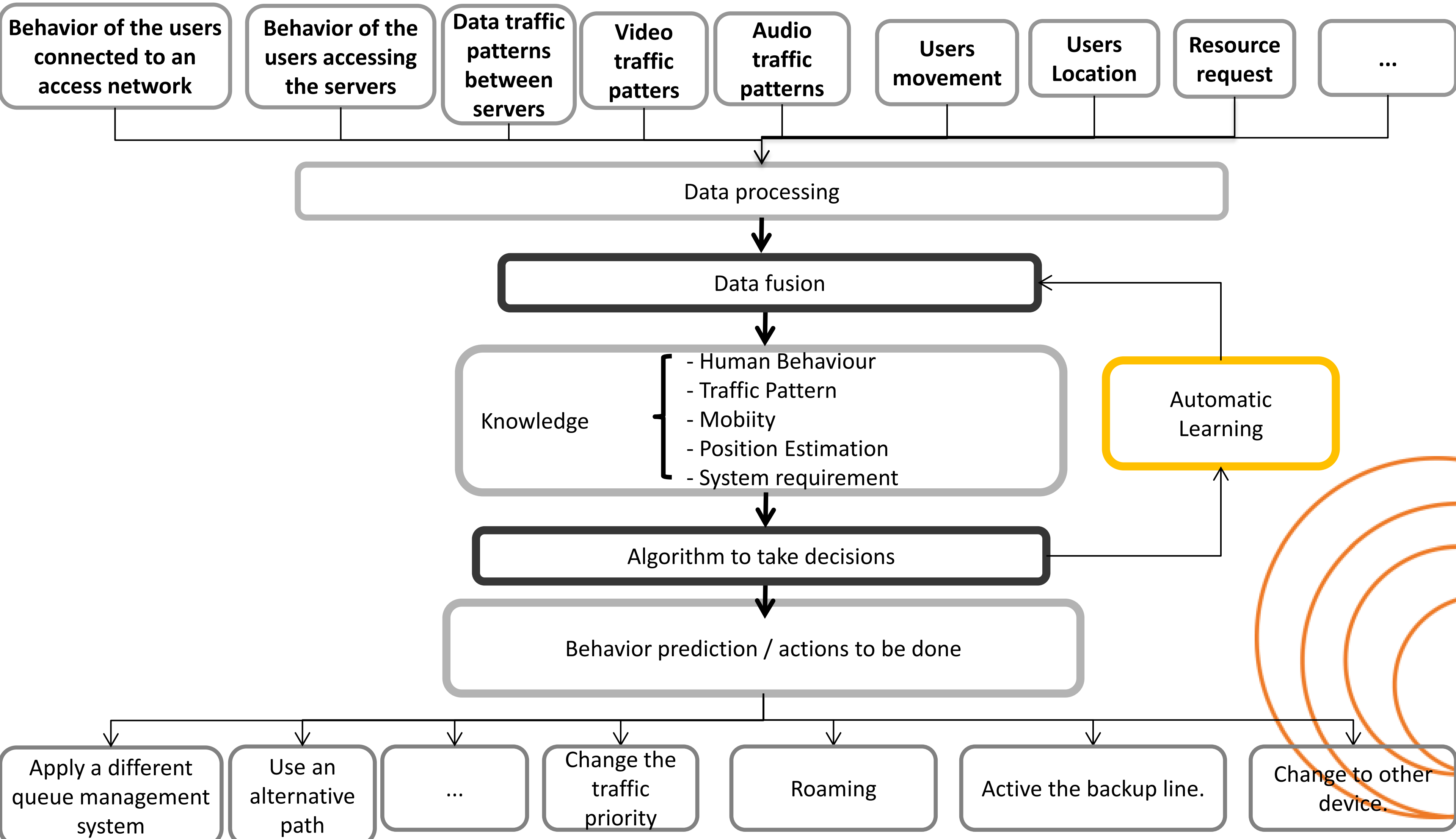
ID	Status	Instance	Last Header
(srcIP, srcPORT, dstIP, dstPORT)	[class1, Npackets1]	Array1	H1
(srcIP, srcPORT, dstIP, dstPORT)	[class2, Npackets2]	Array2	H2

FlowTable & FlowRow Formats

Name	Description
NPACKETS0	Number of packets in the direction 0
NPACKETS1	Number of packets in the direction 1
L0	Accumulative sum of data length in the direction 0
L1	Accumulative sum of data length in the direction 1
L02	Accumulative sum of squared data length in the direction 0
L12	Accumulative sum of squared data length in the direction 1
L0MAX	Maximum data length in the direction 0
L1MAX	Maximum data length in the direction 1
L0MIN	Minimum data length in the direction 0
L1MIN	Minimum data length in the direction 1
PROTO	The transport protocol used (TCP/UDP)

Algorithm learns using inductive inference based on observing gathered data, automatically recognize complex patterns and makes intelligent decisions.

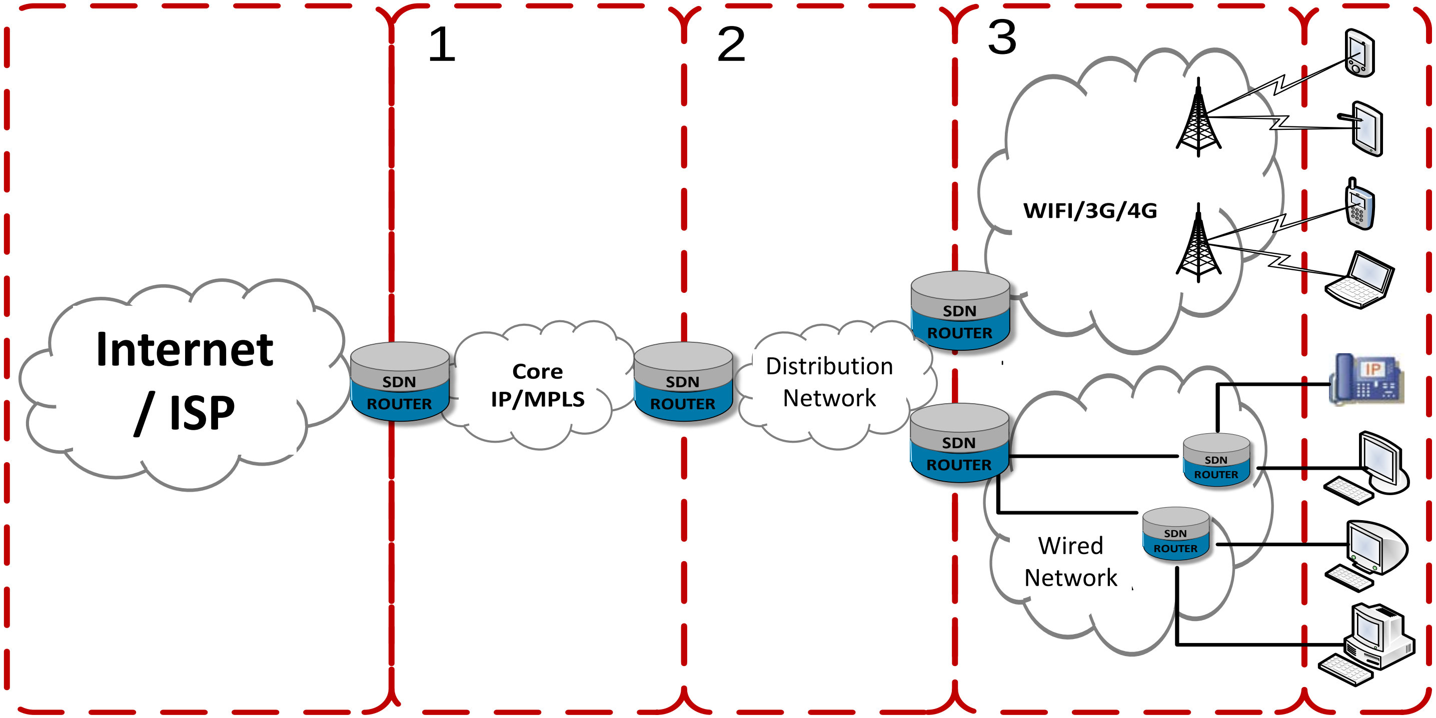
Multimedia delivery Using Artificial Intelligence over SDN



Multimedia delivery Using Artificial Intelligence over SDN

Then, a reasoning engine is conscious of what is happening and will learn from the consequences of its actions to improve future decisions.

Multimedia delivery Using Artificial Intelligence over SDN

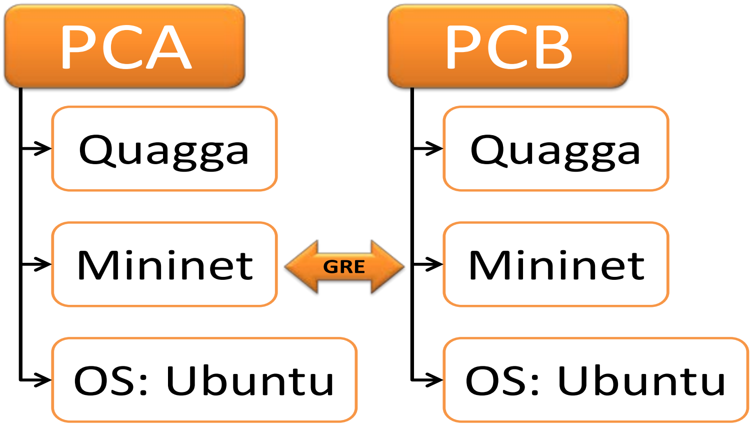


Zones where smart devices can be added

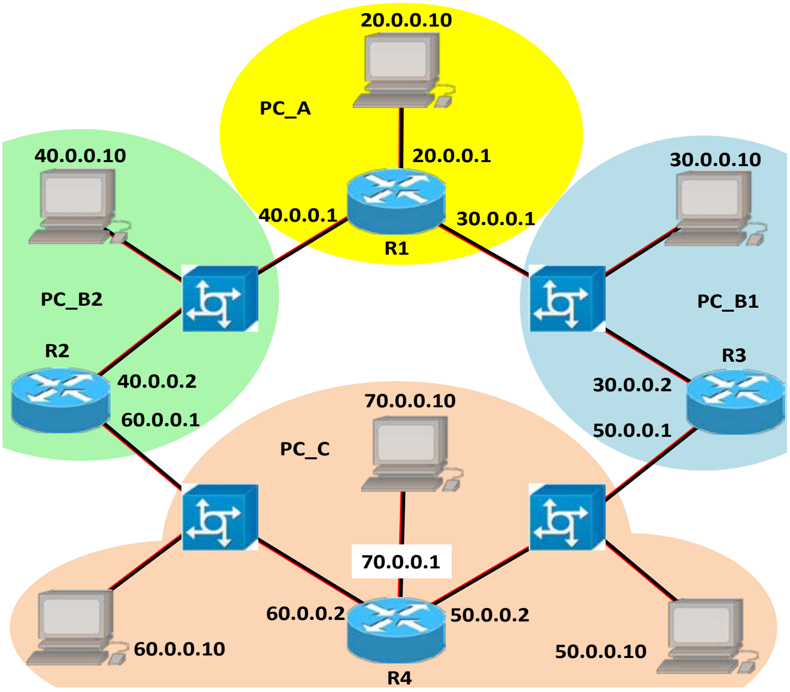
Intelligent Systems can be implemented in a wide range of multimedia applications.

Real Implementations and Performance Tests

Real Implementations and Performance Tests



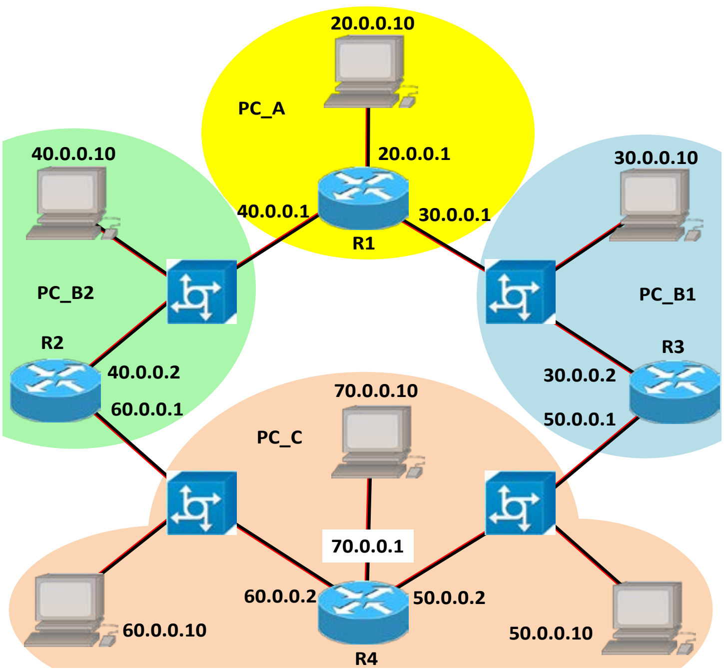
Topology

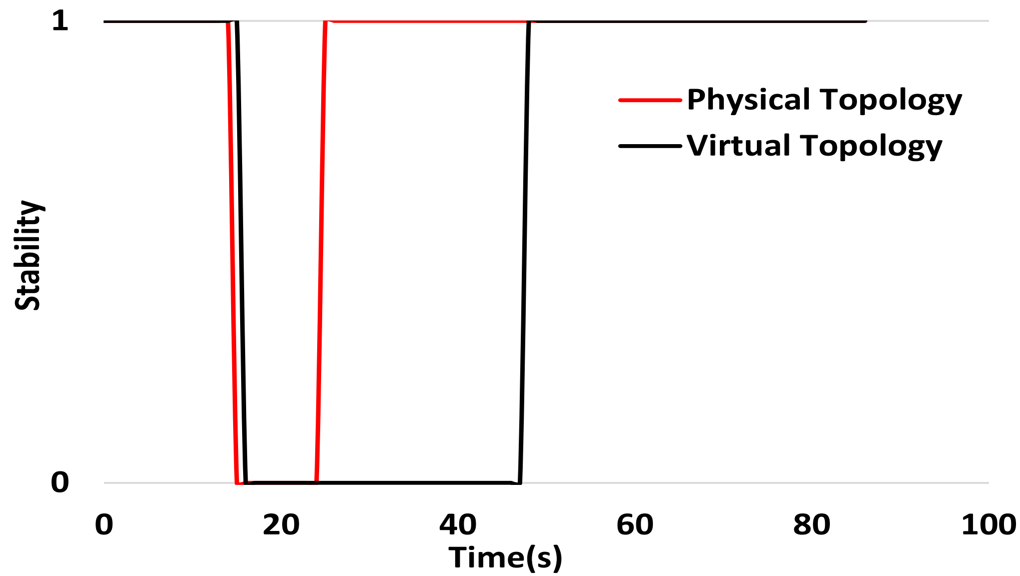


A Rego, S Sendra, JM Jimenez, J Lloret, OSPF routing protocol performance in Software Defined Networks, 2017 Fourth International Conference on Software Defined Systems (SDS), 131-136. 2017,

Real Implementations and Performance Tests

Convergence Time and RTT Tests

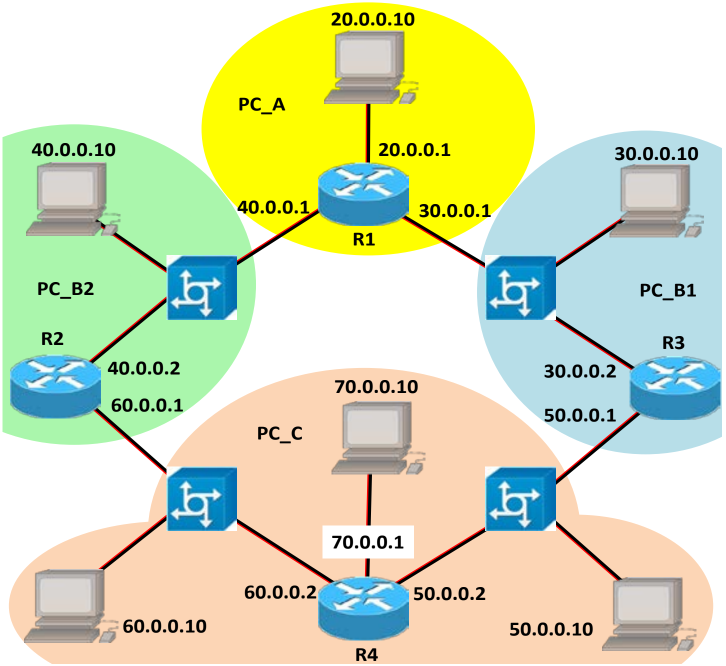


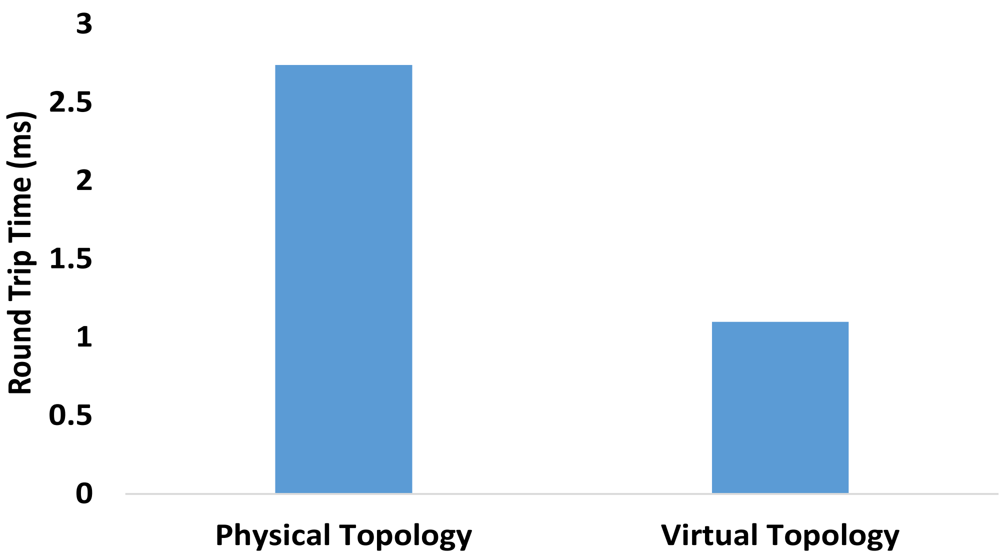


Stability measured in both topologies.

Real Implementations and Performance Tests

Convergence Time and RTT Tests

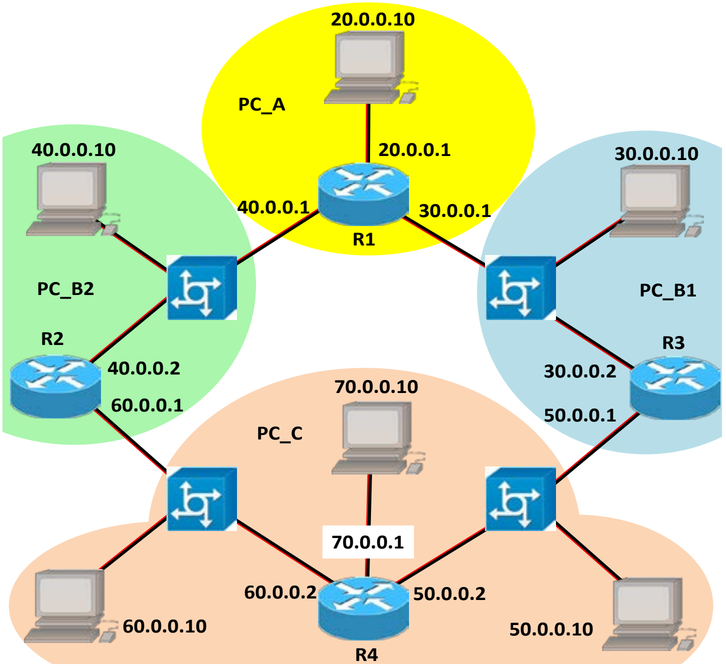


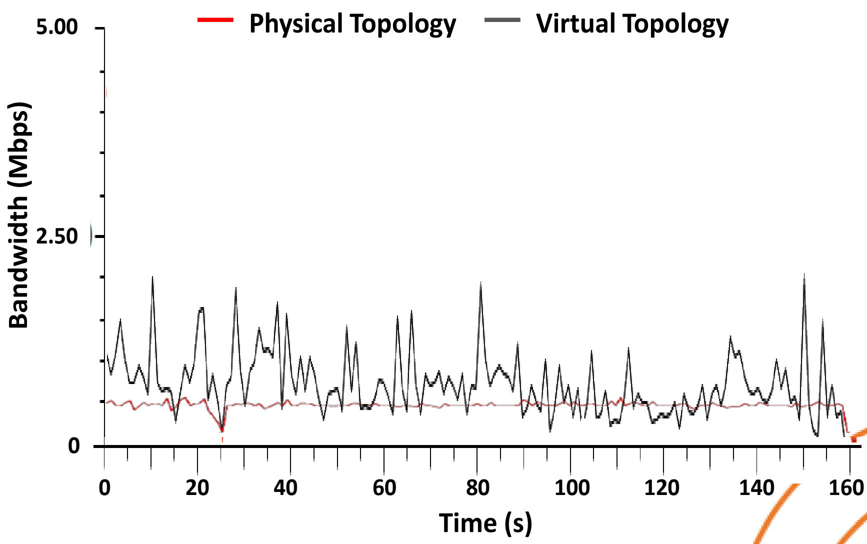


Round-Trip time for both topologies

Real Implementations and Performance Tests

Multimedia QoS test

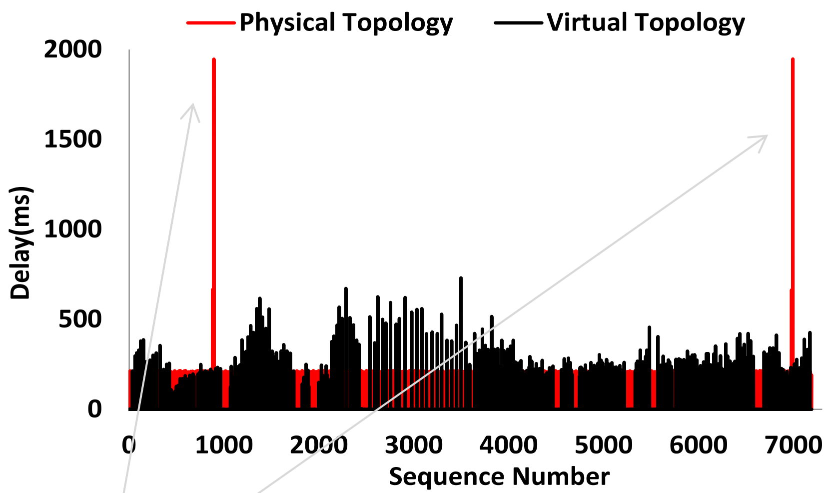




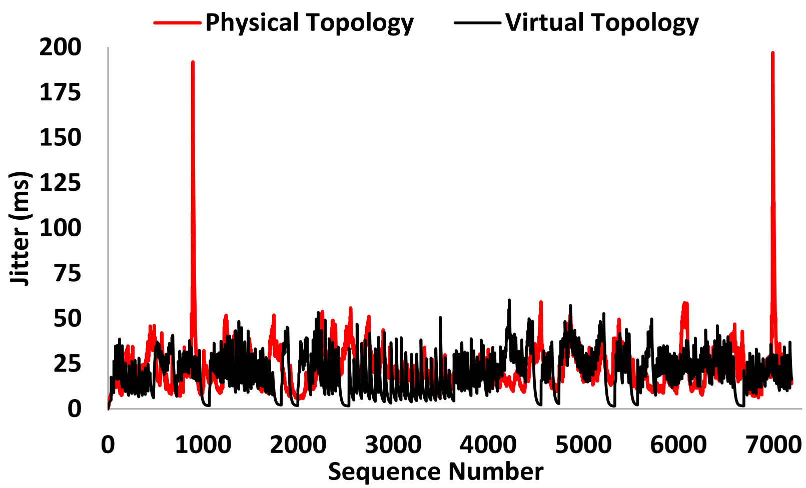
Consumed bandwidth during video streaming for both topologies

Real Implementations and Performance Tests

Multimedia QoS test

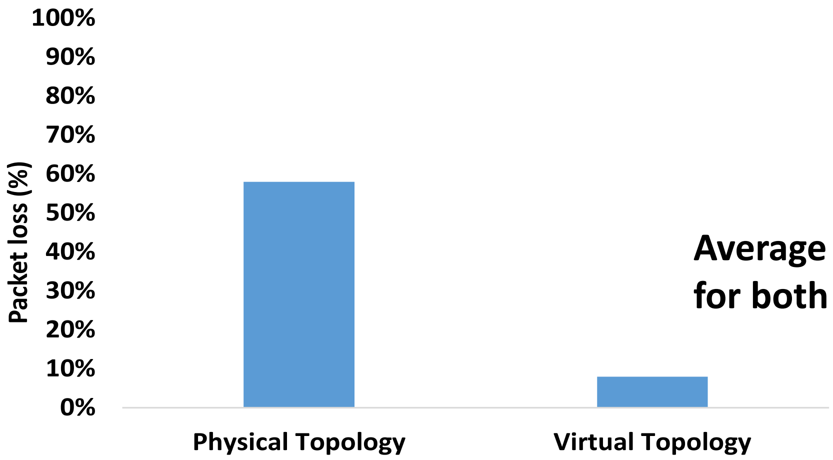


Delay in ms. during video streaming



Jitter in ms. during video streaming

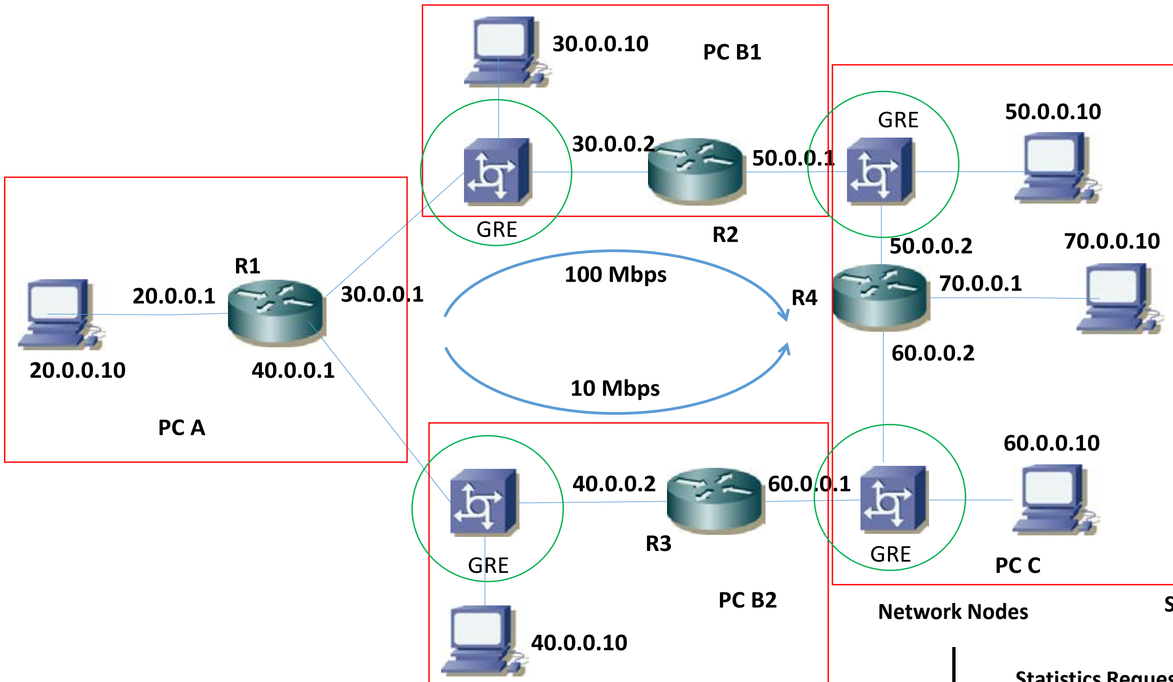
Loss of data bursts

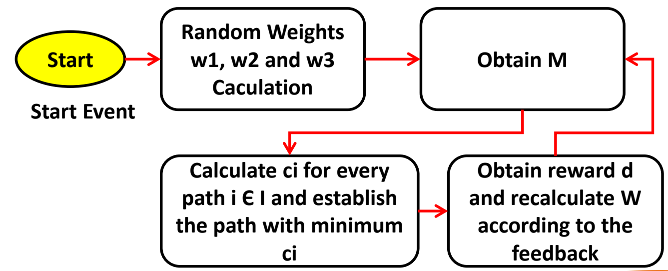


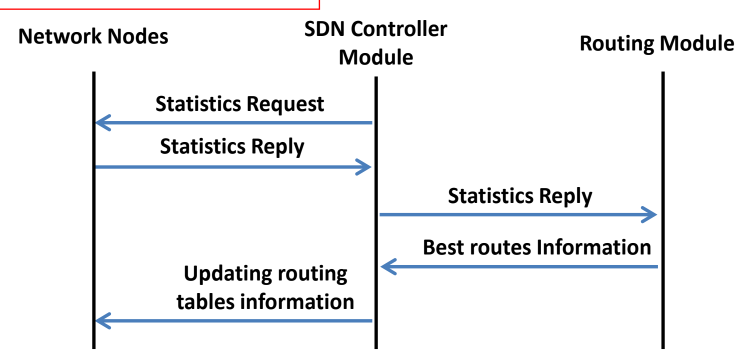
Average value of packet loss in % for both topologies.

Real Implementations and Performance Tests

S Sendra, A Rego, J Lloret, JM Jimenez, O Romero, Including artificial intelligence in a routing protocol using software defined networks, IEEE International Conference on Communications Workshops (ICC 2017). Paris, France, 21-25 May 2017.

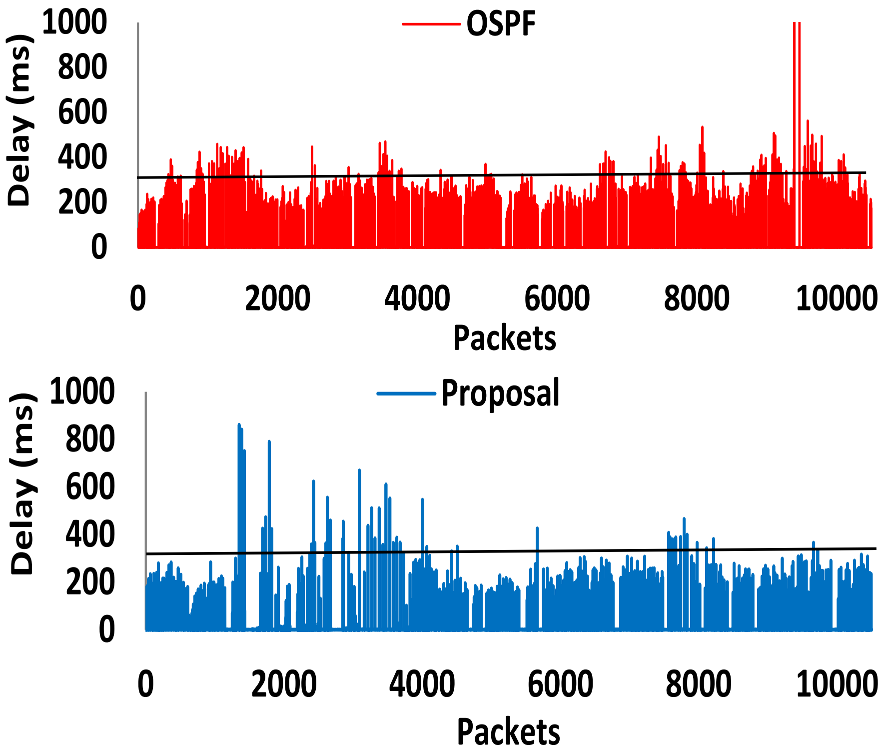




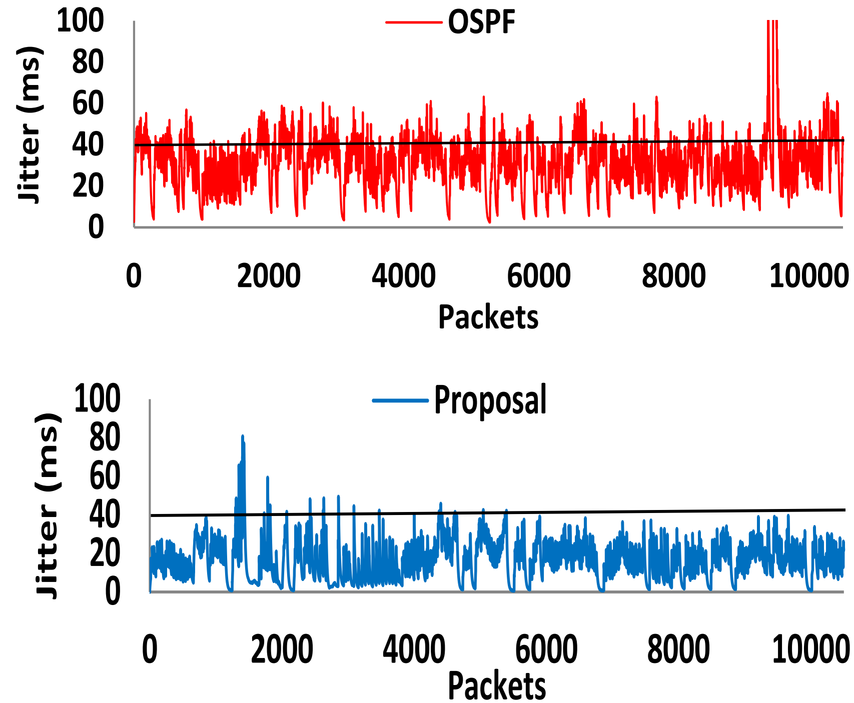


Real Implementations and Performance Tests

Including Artificial Intelligence in a Routing Protocol Using Software Defined Networks



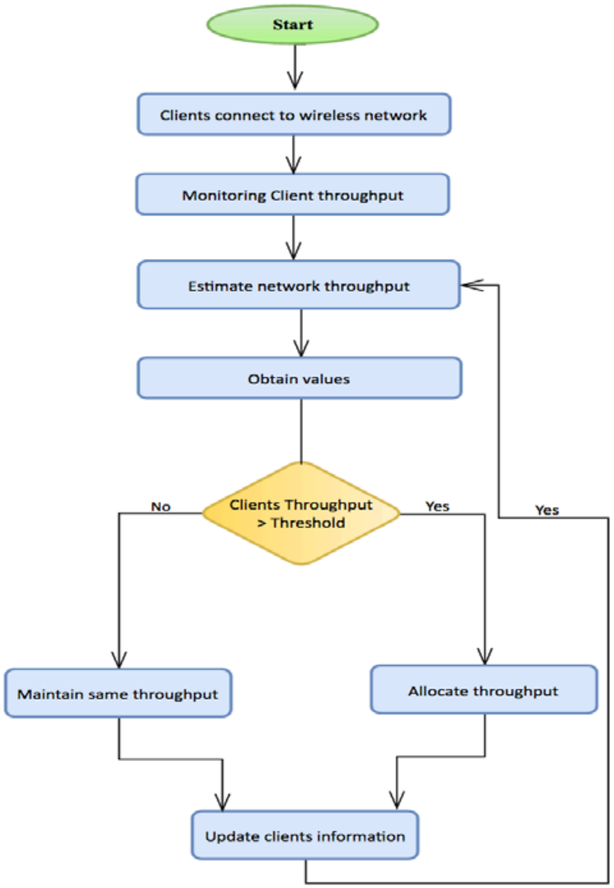
Delay comparison

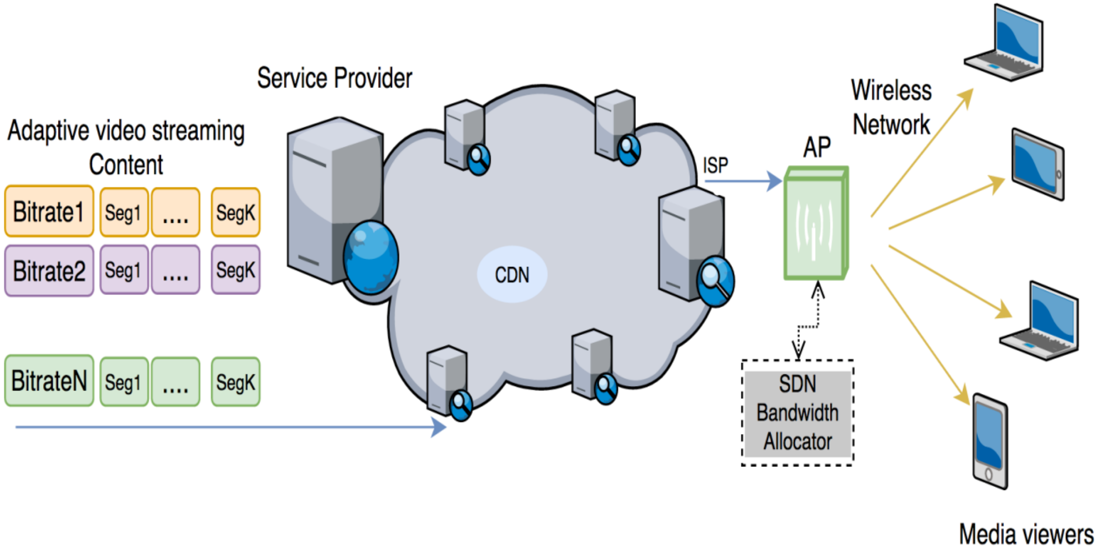


Jitter comparison

Real Implementations and Performance Tests

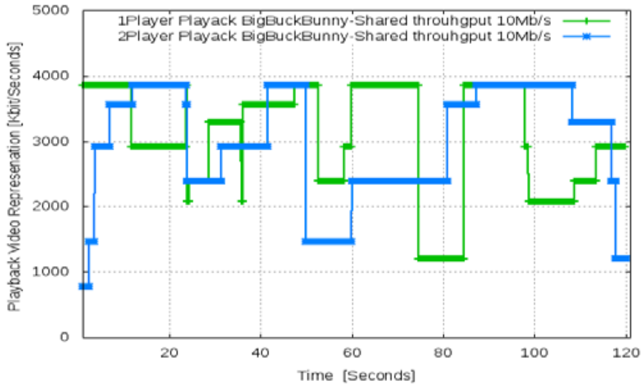
M Taha, L Garcia, JM Jimenez, J Lloret, SDN-based throughput allocation in wireless networks for heterogeneous adaptive video streaming applications, The 13th International Wireless Communications and Mobile Computing Conference (IWCMC 2017), June 26-30, 2017, Valencia.



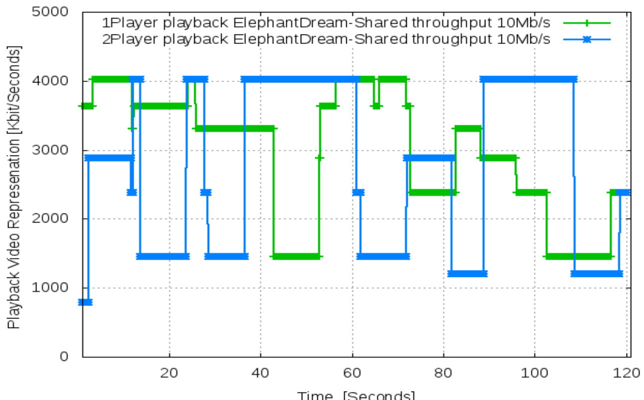


Real Implementations and Performance Tests

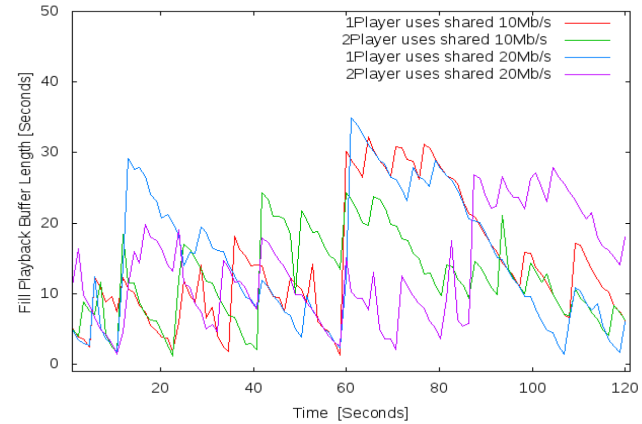
SDN-based Throughput Allocation in Wireless Networks for Heterogeneous Adaptive Video Streaming Applications



Unfairness of the first video streamed over a shared link.



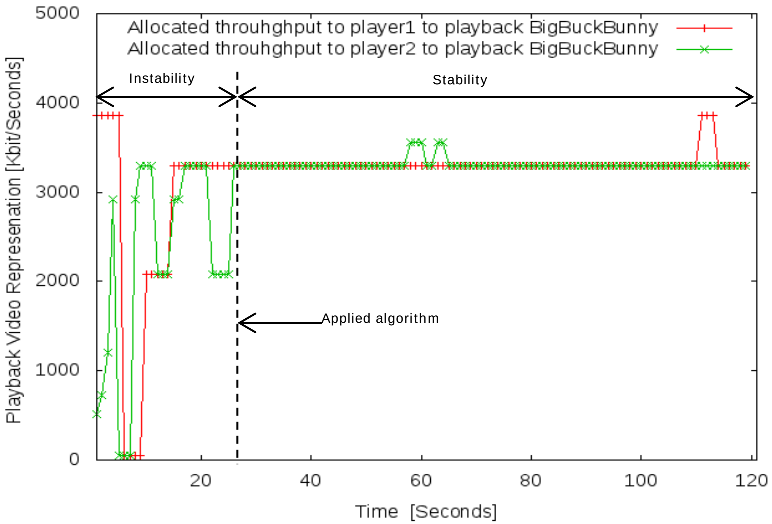
Unfairness of the second video streamed over a shared link.



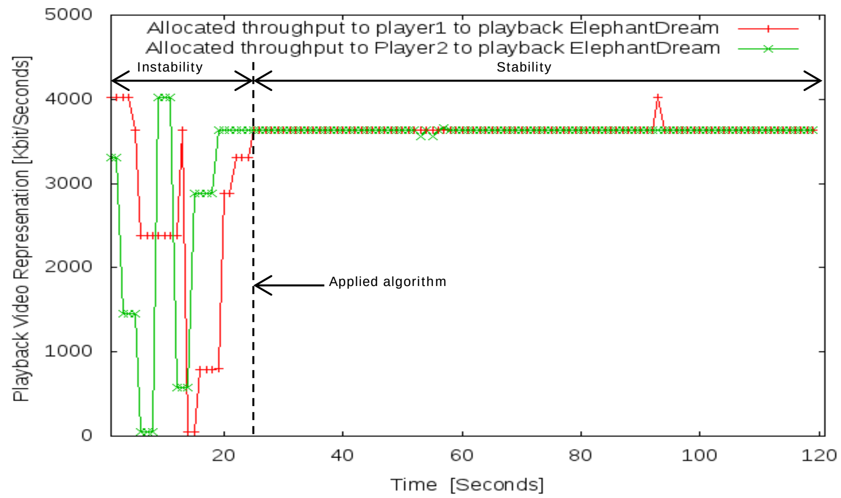
High variation of buffer length.

Real Implementations and Performance Tests

SDN-based Throughput Allocation in Wireless Networks for Heterogeneous Adaptive Video Streaming Applications



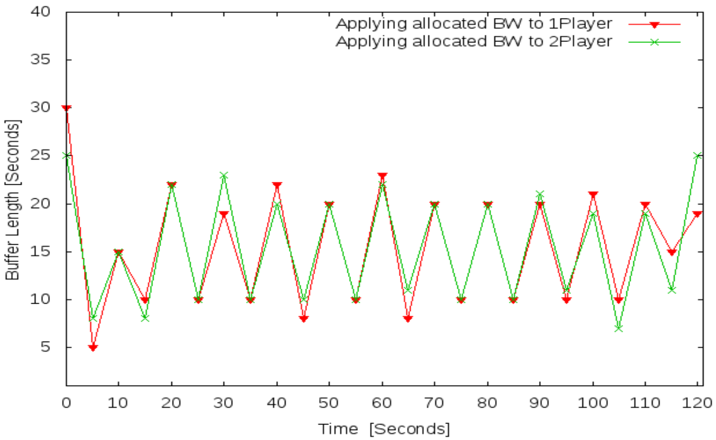
Bandwidth allocation among players to playback first video.



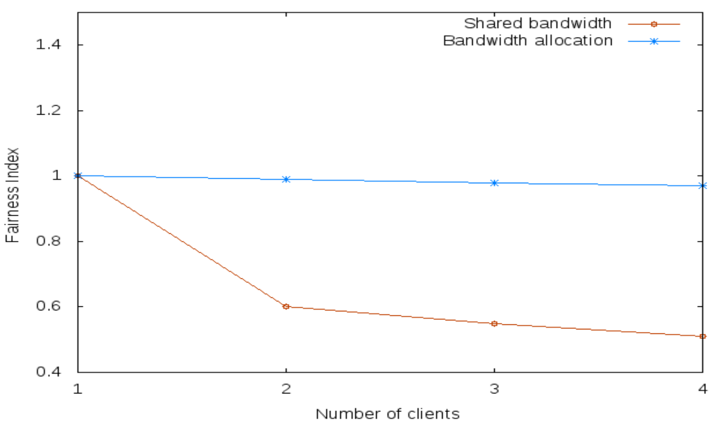
Bandwidth allocation among players to playback second video.

Real Implementations and Performance Tests

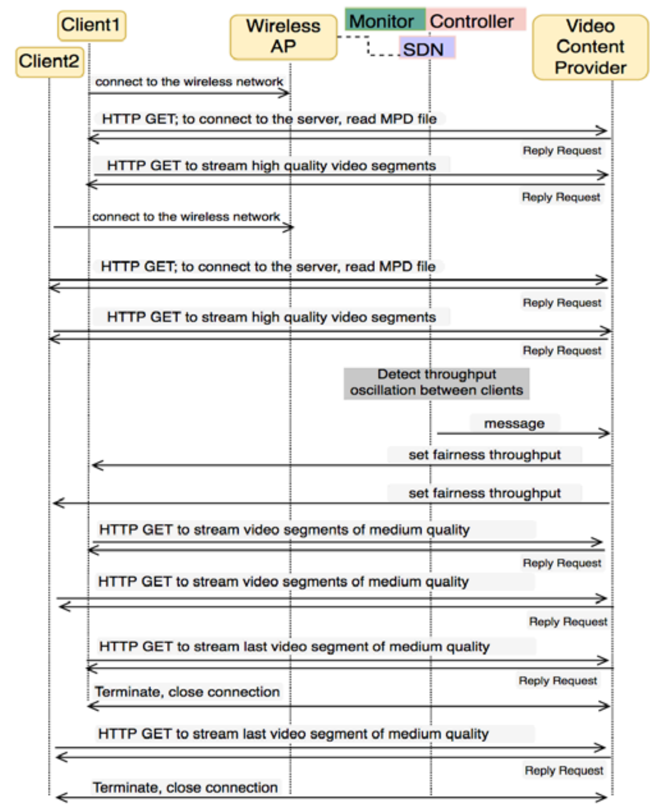
SDN-based Throughput Allocation in Wireless Networks for Heterogeneous Adaptive Video Streaming Applications



Stability of buffer length.



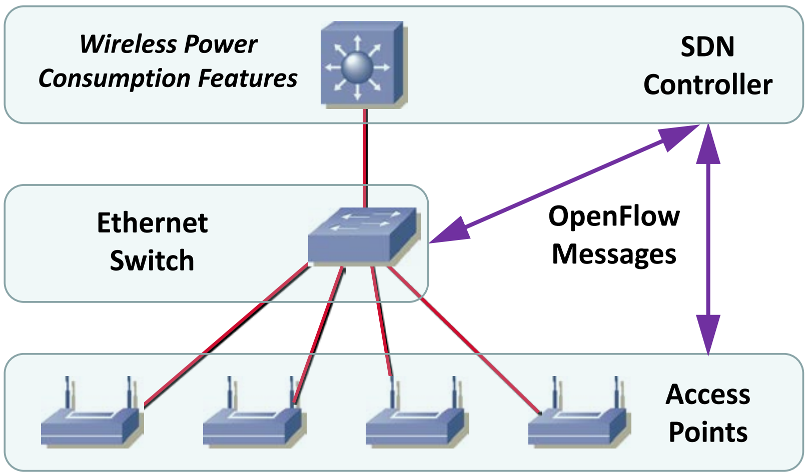
Fairness index with and without bandwidth allocation.

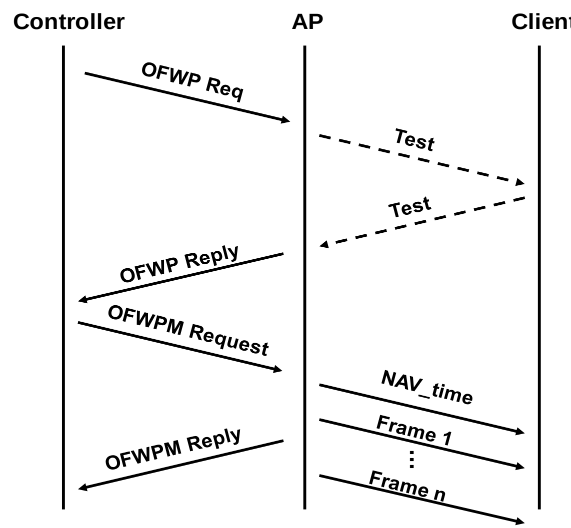


Messages flow in the network topology

Real Implementations and Performance Tests

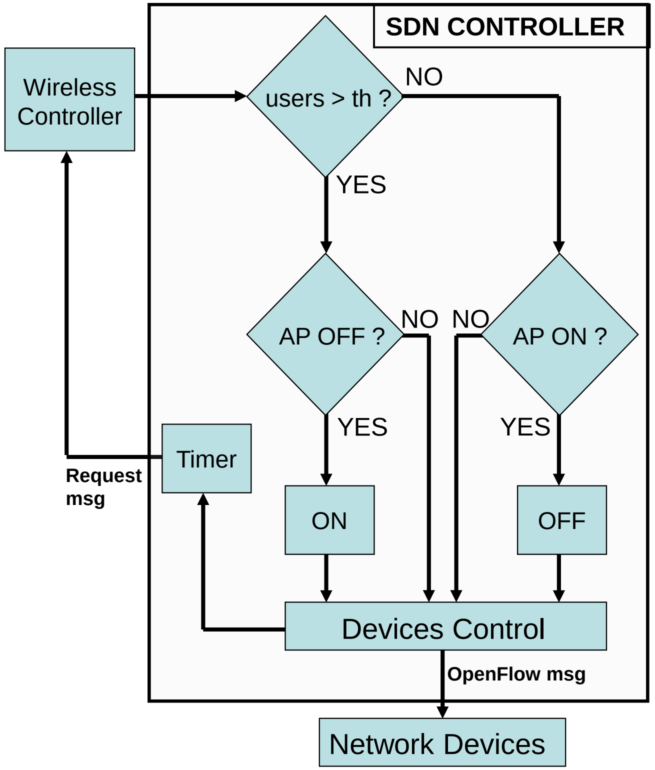
JM Jimenez, O Romero, J Lloret, JR Diaz, Energy savings consumption on public wireless networks by SDN management, Mobile networks and applications, 2016





Real Implementations and Performance Tests

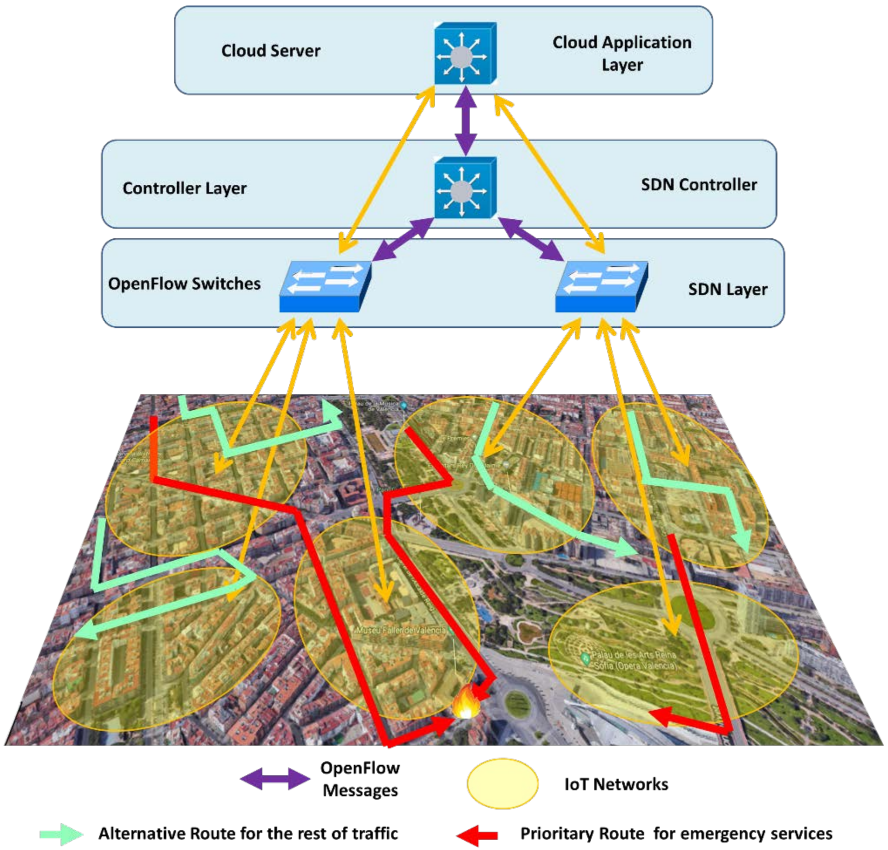
Energy Savings Consumption on Public Wireless Networks by SDN Management



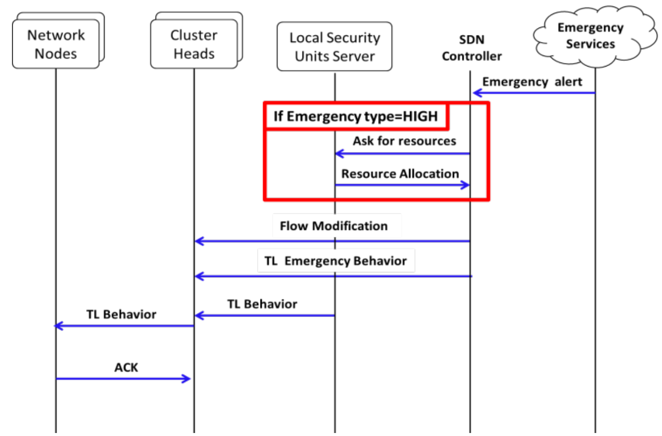
AP Model	General Power Consumption (KW/h)	Saving Power (KW/h)
Aruba IAP 103	164,2	76,8
Aruba RAP-100	216,0	101,0
Cisco Air LAP 1240AG	266,1	124,4
Cisco Aironet 1130AG	210,8	98,6
Cisco Aironet 1230G	224,6	105,0
Aerohive AP121	290,3	135,7
Aerohive AP230	290,3	135,7
Aerohive AP330	290,3	135,7

Real Implementations and Performance Tests

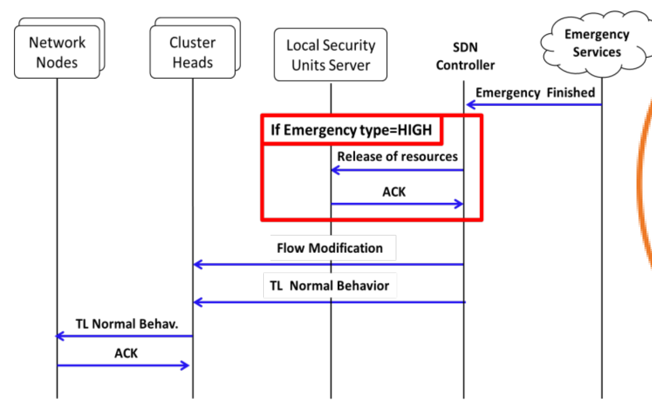
A Rego, L Garcia, S Sendra, J Lloret, Software Defined Network-based control system for an efficient traffic management for emergency situations in smart cities, Future Generation Computer Systems 88, 243-253. 2018



Architecture



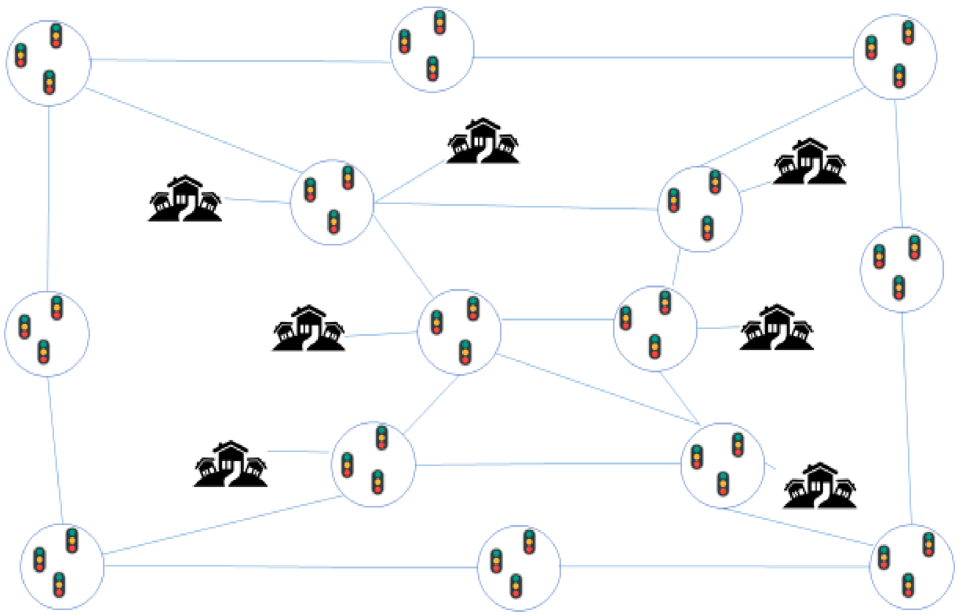
Message exchange when alarm is detected



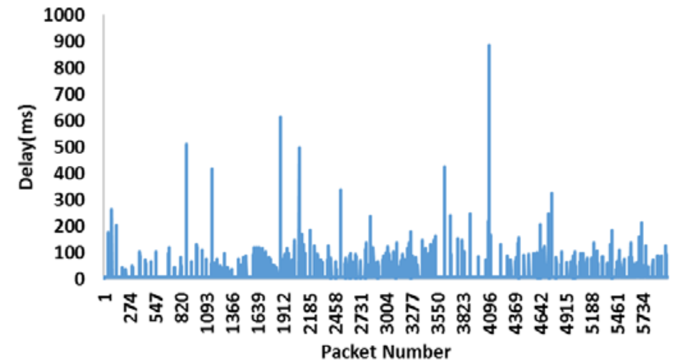
Message exchange when alarm is finished

Real Implementations and Performance Tests

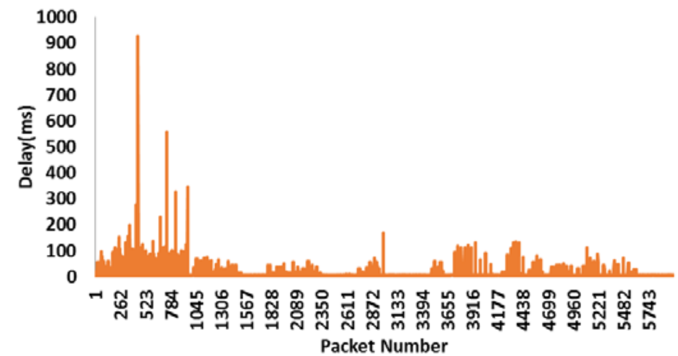
Software Defined Network-based Control System for an Efficient Traffic Management for Emergency Situations in Smart Cities



The smart city is treated as a SDN. There are sets of traffic lights and other traffic elements that interconnect the neighborhood



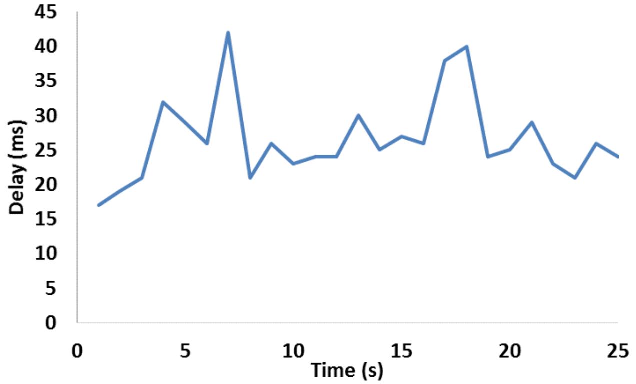
Delay in normal traffic without system application



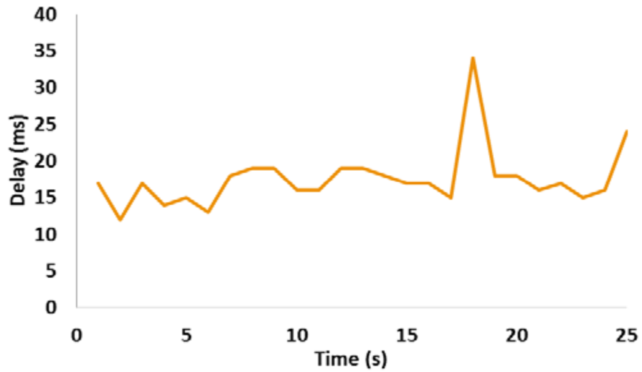
Delay in normal traffic with system application

Real Implementations and Performance Tests

Software Defined Network-based Control System for an Efficient Traffic Management for Emergency Situations in Smart Cities



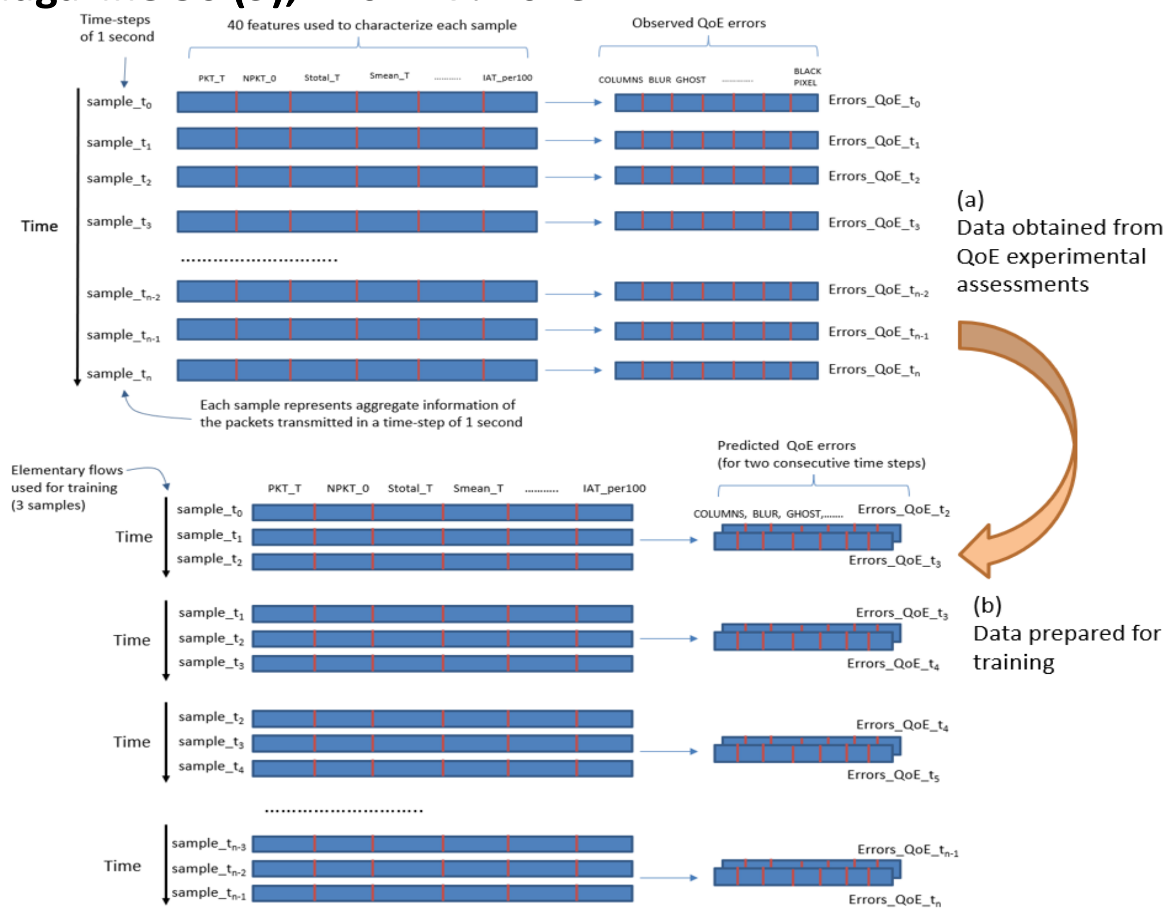
Delay in emergency traffic without system application



Delay in emergency traffic with system application

Real Implementations and Performance Tests

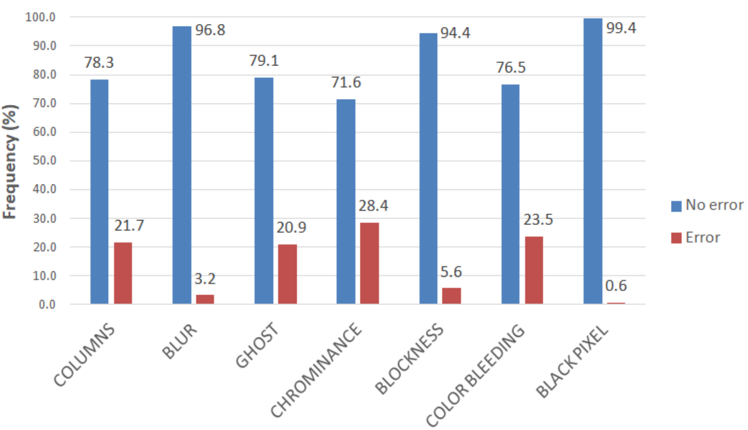
M Lopez-Martin, B Carro, J Lloret, S Egea, A Sanchez-Esguevillas, Deep Learning Model for Multimedia Quality of Experience Prediction Based on Network Flow Packets, IEEE Communications Magazine 56 (9), 110-117. 2018



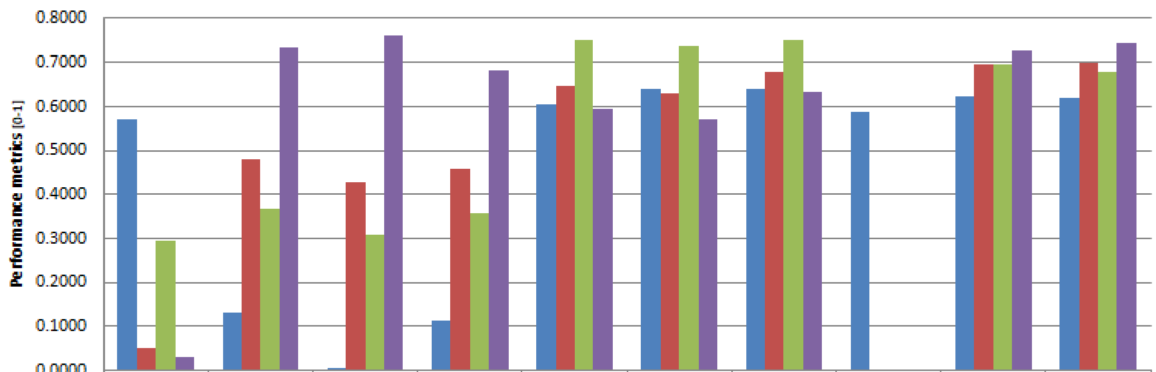
Training data formed by aggregate data samples (a) and final configuration of the training data (b)

Real Implementations and Performance Tests

Deep learning model for multimedia Quality of Experience prediction based on network flow packets



Frequency distribution for QoE label values.



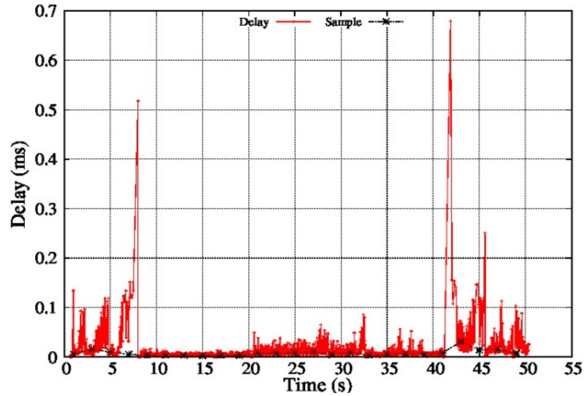
	MLP	Linear SVC	SVC - RBF Kernel	Logistic Regression	GBM	Adaboost	Random Forest	Model 1: RNN	Model 2: CNN+RNN	Model 3: CNN+RNN+GP
Accuracy	0.5705	0.1314	0.0064	0.1122	0.6058	0.6410	0.6378	0.5865	0.6218	0.6186
F1	0.0512	0.4799	0.4286	0.4585	0.6476	0.6301	0.6787	0	0.6965	0.6987
Precision	0.2938	0.3676	0.3098	0.3570	0.7495	0.7356	0.7513	0	0.6949	0.6792
Recall	0.0305	0.7327	0.7618	0.6814	0.5942	0.5693	0.6330	0.0000	0.7271	0.7424

Performance metrics (aggregated) for QoE classification for all models

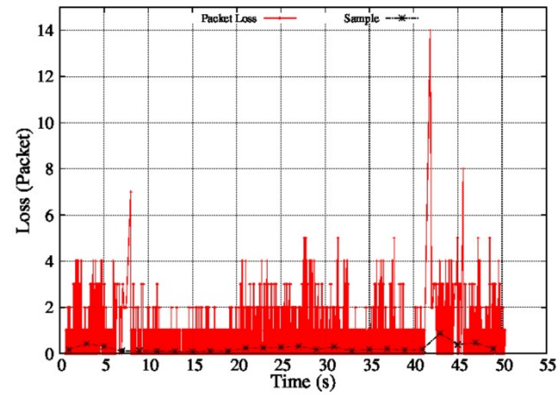
Real Implementations and Performance Tests

A Canovas, JM Jimenez, O Romero, J Lloret, Multimedia Data Flow Traffic Classification Using Intelligent Models Based on Traffic Patterns, IEEE Network 32 (6), 100-107, 2018.

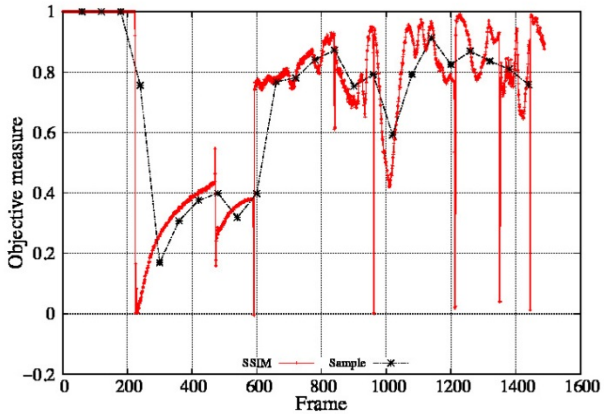
(a)



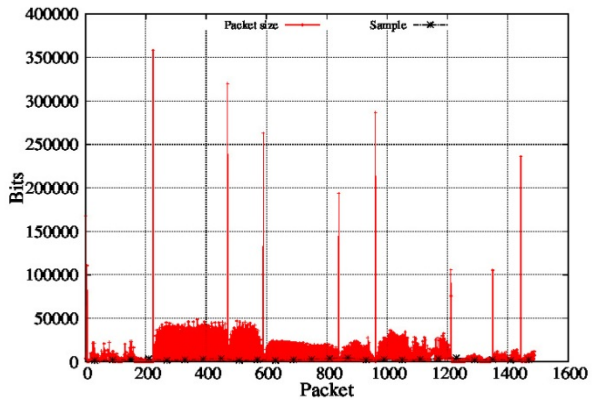
(b)



(c)



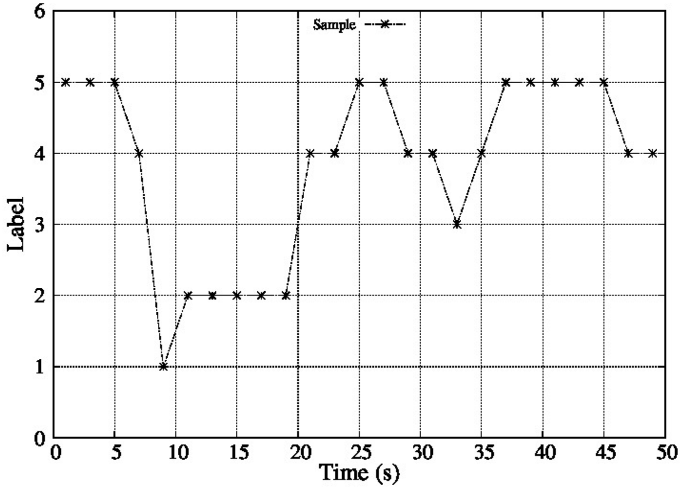
(d)

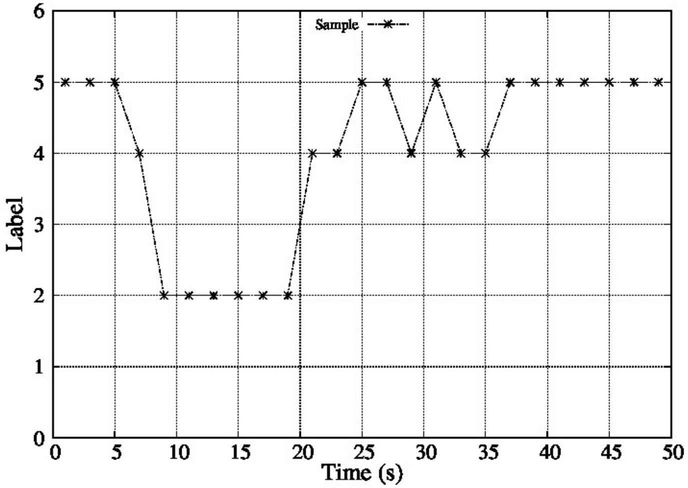


Samples extraction from network parameters, video quality received and video streaming during transmission. From left to right, and from top to bottom: (a) delay sampling, (b) packet loss sampling, (c) received quality sampling based on SSIM,and (d) size of received video flow.

Real Implementations and Performance Tests

Multimedia Data Flow Traffic Classification using Intelligent Models based on Traffic Patterns

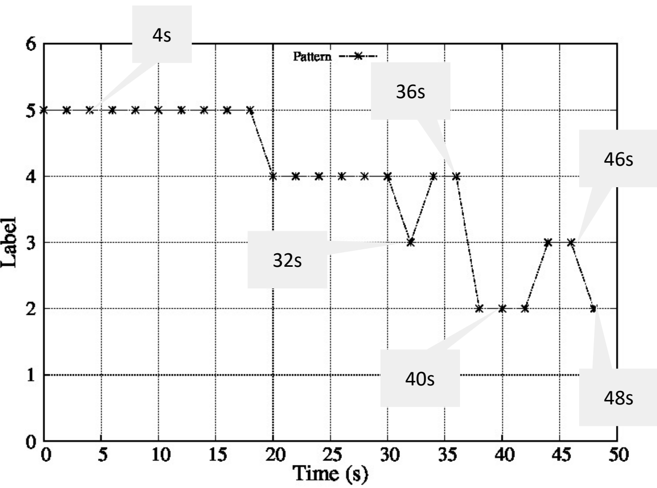


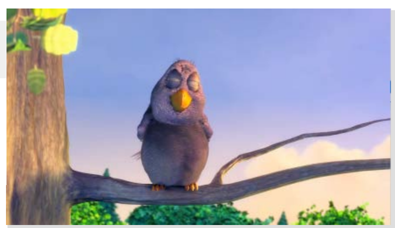


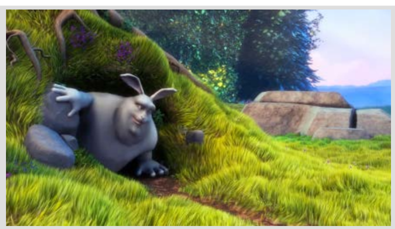
Multimedia traffic quality patterns extraction. Left (a), pattern based on ISSM. Right (b), pattern based on PSNR, ISSM, VQM and NQI combination.

Real Implementations and Performance Tests

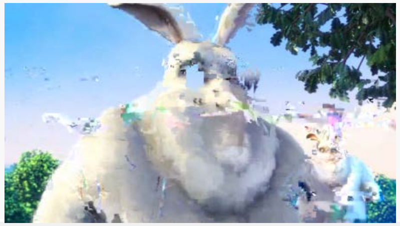
Multimedia Data Flow Traffic Classification using Intelligent Models based on Traffic Patterns







4s - OK	32s – min. Line Pixel error	36s - OK



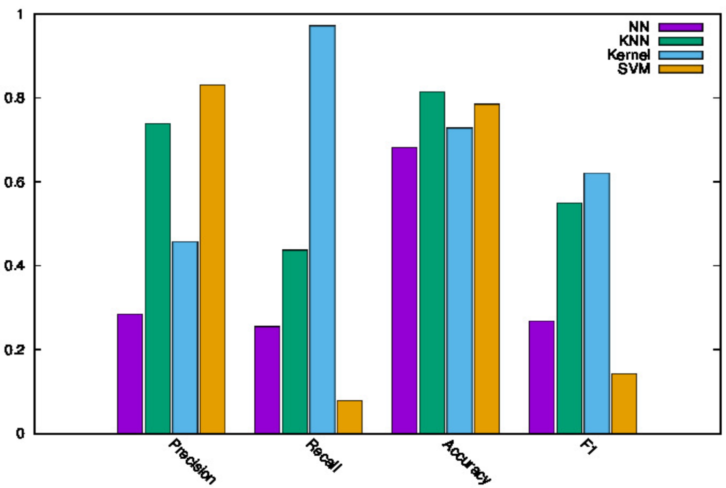
40s – Ghost+Blur	46s – min. Pixel + min. Error Chrominance.	48sGhost+Blur

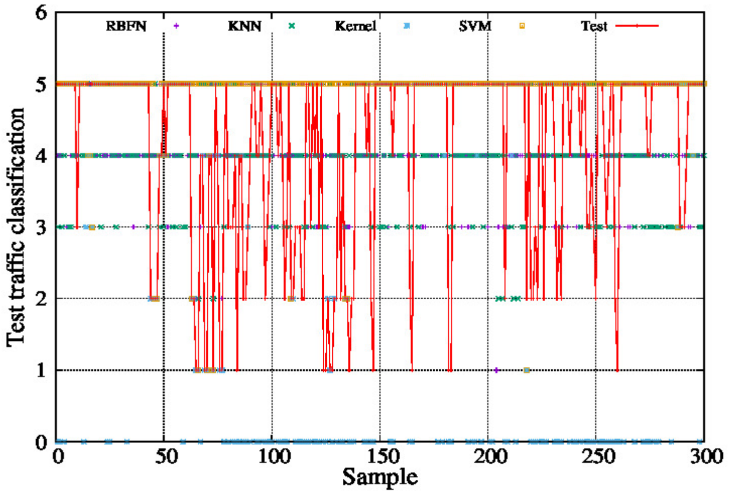
Real Implementations and Performance Tests

Multimedia Data Flow Traffic Classification using Intelligent Models based on Traffic Patterns

There are 5 labels that represent the type of traffic during the video transmission:

Non critical
Low critical
Some critical
Critical
Very critical

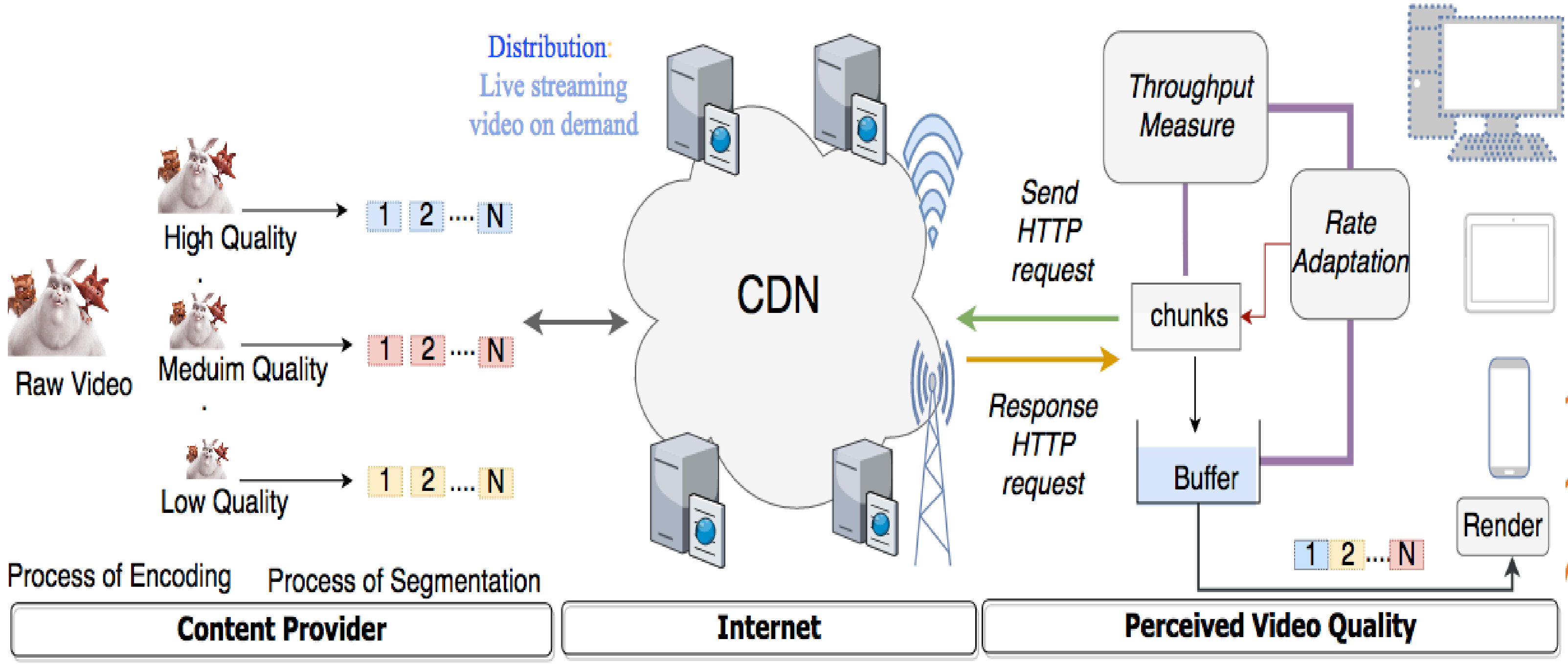




Results of classification based on the different methods. Top, (a), Accuracy level. Bottom, (b), Traffic Classification.

Real Implementations and Performance Tests

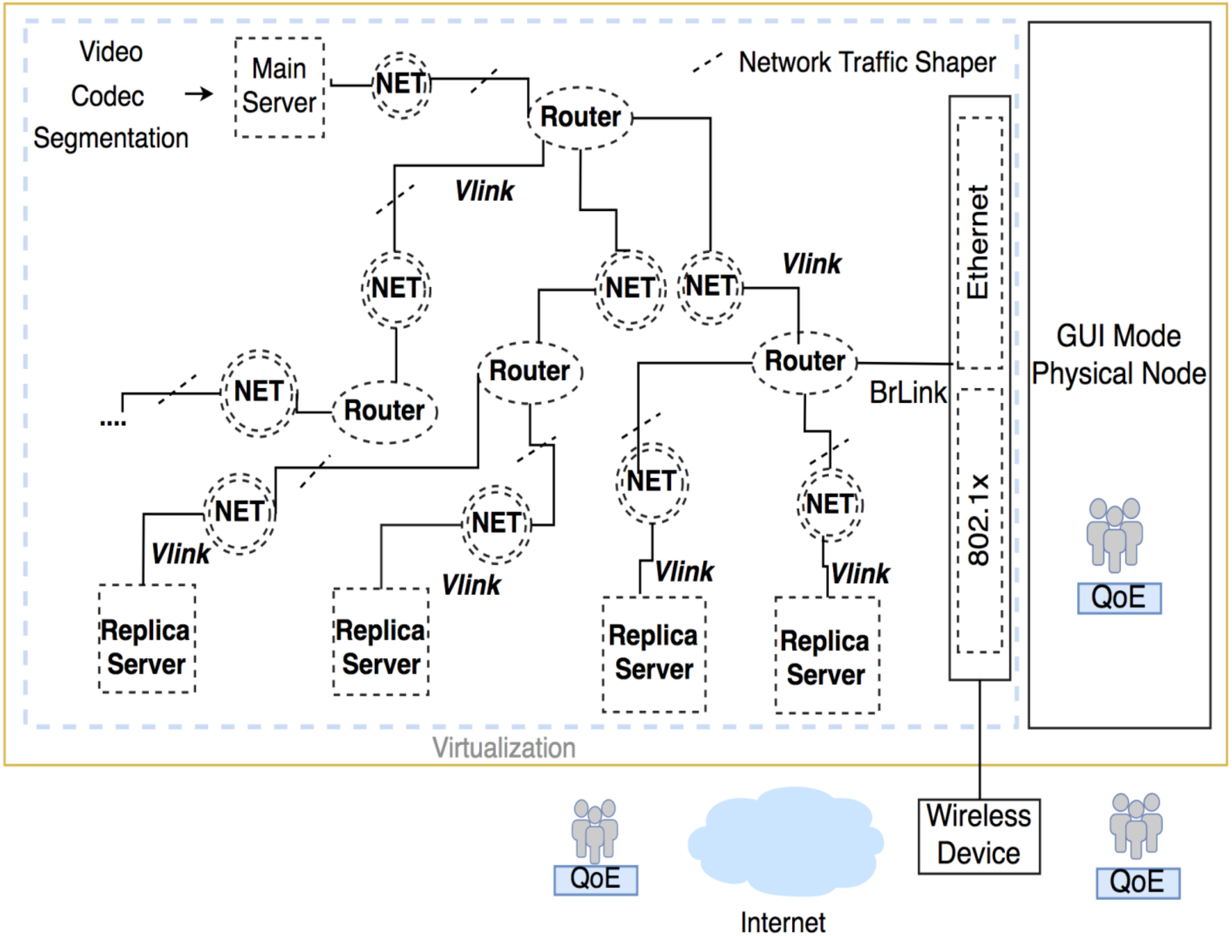
M Taha, J Lloret, A Ali, L Garcia, Adaptive video streaming testbed design for performance study and assessment of QoE, International Journal of Communication Systems 31 (9), e3551, 2018



Real Implementations and Performance Tests

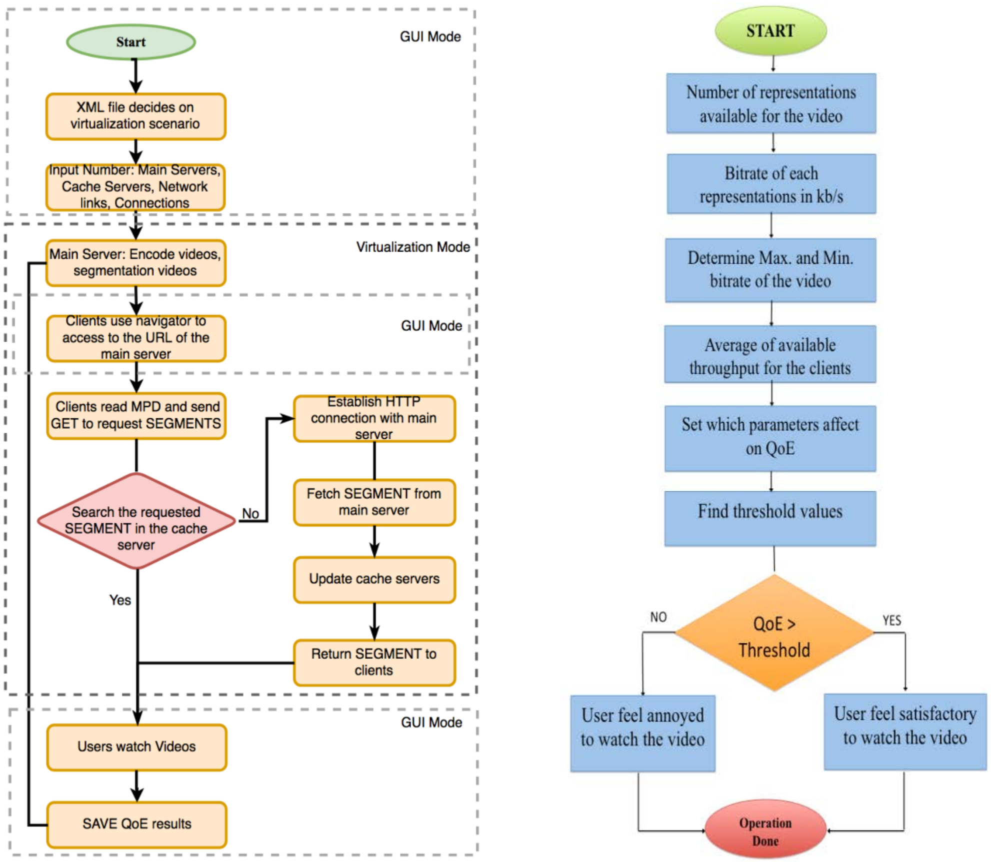
Adaptive Video Streaming Testbed Design for Performance Study and Assessment of QoE

Topology of the proposed system



Real Implementations and Performance Tests

Adaptive Video Streaming Testbed Design for Performance Study and Assessment of QoE



System algorithm: (a) Operation functional view, (b) QoE evaluation

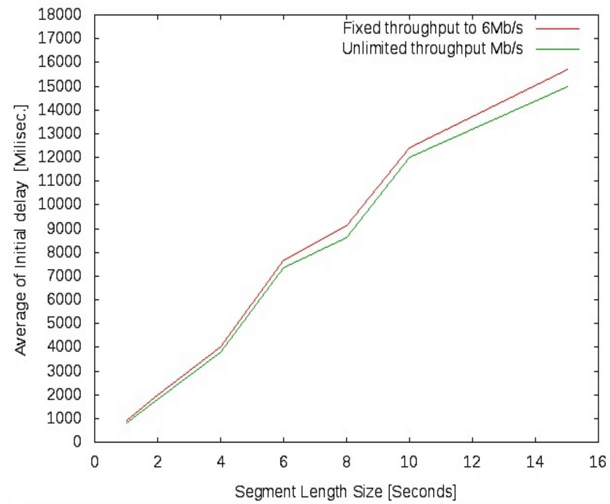
Real Implementations and Performance Tests

UNIVERSITAT POLITÈCNICA DE VALÈNCIA
CAMPUS DE GANDIA

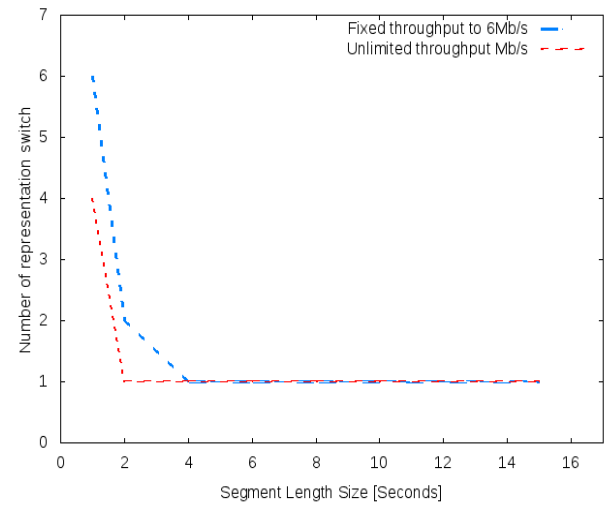
Instituto de investigación para la gestión integrada de zonas costeras

Adaptive Video Streaming Testbed Design for Performance Study and Assessment of QoE

(a)

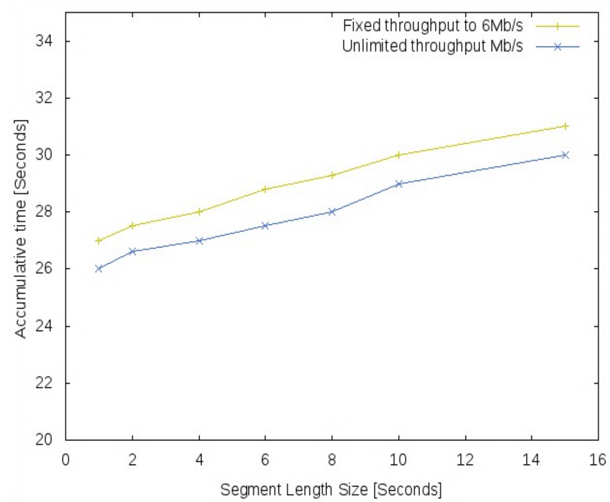


(b)

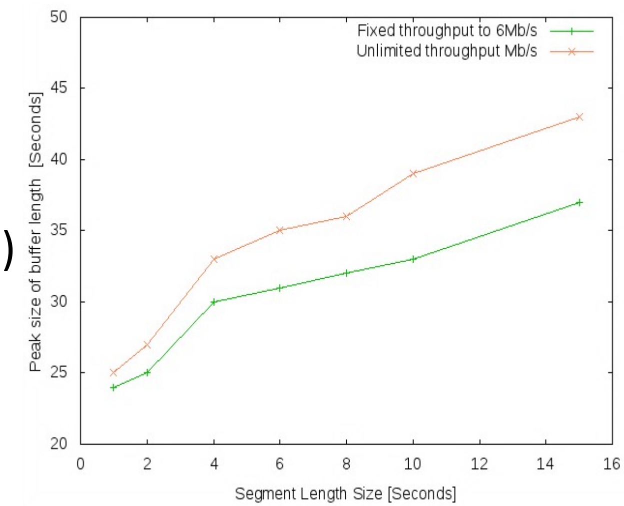


QoE metrics:
a) Initial delay,
b) Quality oscillation,
c) Accumulative time,
d) Maximum buffer size.

(c)



(d)



Real Implementations and Performance Tests

Adaptive Video Streaming Testbed Design for Performance Study and Assessment of QoE

Testbed name	Simulate testbed Ref. [29]	Real testbed Ref. [30]	Simulate testbed Ref. [31]	Simulate testbed Ref. [35]	Flamingo Ref. [43]	Our Proposed testbed
Tested physical	1 Node	5 Nodes	1 Node	1 Node	1 Node	1 Node
Mobility	Easy	Low	Easy	Easy	Easy	Easy
Scalability	High	Low	Medium	High	High	High
Cost efficiency and dollar-cost per device	Medium	High	Low	Medium	Medium	Medium
QoE Method based on	-	-	-	-	-	Decision algorithm.
QoE Metrics	Only video quality oscillation	Initial delay, video stalls, switch frequency	CPU, TCP.	Video stalls, buffer size, switch frequency, MOS	QoE based only on (MOS)	Initial delay, buffer length, video stalls, switch frequency, DMOS, CPU and energy
Realism	Combine of Simulation and emulation	%100 Real	Simulation (Math. Models)	Simulation (Math. Models)	Combine of Simulation and emulation	Emulation (Live network)
Topology of the core network (routers and switches) based on	Simulation	Real	Simulation	Simulation	Simulation	Emulation
Cache service	-	-	-	-	Support	Support
Machine Learning-based Virtual Network	-	-	-	-	Support	No defined yet
Preferable segment length	Not defined	Small segments	Not defined	Not defined	Not defined	6-8 seconds duration
Language used for describing the simulation	Python	-	-	-	Python	XML
VMs Operating system based	Linux	-	-	-	Linux	Linux
VMs Chain distribution	-	-	-	-	-	Support
Network topology presented for experiments	Simple	Simple	Simple	Simple	Complex	Complex
Description	Virtualized network testbed to perform experiments by Mininet	Real nodes to design real testbed to experiment the QoE	Simulate Platform for mobile video streaming using OPNET.	Simulate Platform for LTE-mobile video streaming using ns-3	Virtualized network testbed to perform experiments by Mininet	Virtualized network testbed to perform experiments and run several virtual nodes on a single physical machine

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J. Lloret, A. Canovas, J. Tomas, M. Atenas, **A Network Management Algorithm and Protocol for Improving QoE in Mobile IPTV**, Computer Communications, Vol. 35, Issue 15, Pp. 1855-1870, Sep. 2012.

M. Garcia, S. Sendra, C. Turro, J. Lloret, **User's Macro and Micro-mobility Study using WLANs in a University Campus**, International Journal On Advances in Internet Technology, Vol. 4, Issue 1&2, Pp. 37-46 July 2011.

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Sandra Sendra, Albert Rego, Jaime Lloret, Jose Miguel Jimenez, Oscar Romero, **Including Artificial Intelligence in a Routing Protocol Using Software Defined Networks**, May 21-25, 2017, ICC 2017, Paris (France)

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Jamil Ahmad, Khan Muhammad, Jaime Lloret, and Sung Wook Baik, **Efficient Conversion of Deep Features to Compact Binary Codes Using Fourier Decomposition for Multimedia Big Data**, IEEE Transactions on Industrial Informatics, January 2018

Khan Muhammad, Rafik Hamza, Jamil Ahmad, Jaime Lloret, Haoxiang Wang, and Sung Wook Baik, **Secure Surveillance Framework for IoT Systems Using Probabilistic Image Encryption**, IEEE Transactions on Industrial Informatics, January 2018

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Miran Taha, Jaime Lloret, Aree Ali, Laura Garcia, **Adaptive Video Streaming Testbed Design for Performance Study and Assessment of QoE**, International Journal of Communication Systems, In press.

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Albert Rego, Alex Canovas, Jose M. Jimenez and Jaime Lloret, **An Artificial Intelligence System for QoS and QoE Guarantee in IoT using Software Defined Networks**, IEEE Access, In Press

Manuel Lopez-Martin, Belen Carro, Jaime Lloret, Santiago Egea, Antonio Sanchez-Esguevillas, **Deep learning model for multimedia Quality of Experience prediction based on network flow packets**, IEEE Communications Magazine, in press.

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