A First Study on Video Transmission Over a Nanowireless Network

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Outline

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- Conclusion & Future Works

Motivation

- Nanosensors promise to generate, process, and transmit multimedia content at nano scale
- Very high data rate (theoretically up to several Tbps) in a huge bandwidth (0.1-10 THz)
- In a previous work, we have studied the integration of wireless capabilities in micro-robots of the Claytronics project, showing the enhancement created by wireless communications

Motivation

- Nanocameras could be developed with
  - high sensitivity
  - very low power consumption [1]
- Nanosensors must harvest the energy by converting vibrational, fluidic, electromagnetic or acoustic energy into electrical energy
- A nanosensor could harvest more energy than it will use for packet transmission [2]
- The above properties, allow video application at nanoscale

Motivation

- Video application in nano sensor networks would be used in many fields:
- Application in bio-medical
  - Detect and destroy: Virus, Bacteria [3], Fungi
  - Drug delivery system for disease treatment
  - Observe inner organ with minimum or no surgery
- Application in advance multimedia
  - Real 3D holographic teleconference
  - Advance smart dust technology
- Application in military
  - Nuclear monitoring (in nanoscale)
  - Biological and chemical defenses

Method

- Performance of video application in nano sensor networks needs to be investigated through simulation

- Tools available (NS 3):
  - NanoSim: Throughput and Delay
  - QoE Monitor: Peak Signal to Noise Ratio (PSNR), Structural Similarity (SSIM), and Jitter

Method - NanoSim

- NanoSim allows to evaluate Wireless NanoSensor Networks (WNSN) performance [4]
- NanoSim comprises three types of WNSN devices:
  - Nanonode: It is the smallest device and it can be seen as a sensor collecting information such as chemical reaction or multimedia content (sound, image and video). This device has limited capabilities in computational, storage and communication range

Method - NanoSim

- Nanorouter: This device has larger capabilities than a nanonode, it can receive and forward information to the nanointerface or to other nanorouter

- Nanointerface: This device can be considered as the sink which process information from sensors. This device can also be used as a gateway to another network e.g: WiFi, LTE, etc

Method - NanoSim

- The network architecture consists of four layers:
  - Application Layer (Message Processing Unit class)
    - Generates packets using Constant Bit Rate (CBR)
    - Receives packets from the lower layer
  - Network Layer
    - Receives/forwards packets between nanosensors and nanorouters to nanointerfaces

Method - NanoSim

- Medium Access Control (MAC)
  - Transmits packets from network layer to physical layer without any control
  - Sends the packets when at least one node is in its transmission range
- Physical Layer.
  - Operates in Terahertz spectrum using TS-OOK modulation

Method - QoE

- Quality of Experience (QoE) Monitor is an NS3 module
- Computes PSNR and SSIM metrics
- At the transmitter side, the video source uses the RTP protocol to fragment the original video into packets.
- Sender: header information like packet ID, payload size, and timestamps are added.
- Receiver: extracts the header from each packet and creates the reconstructed video.

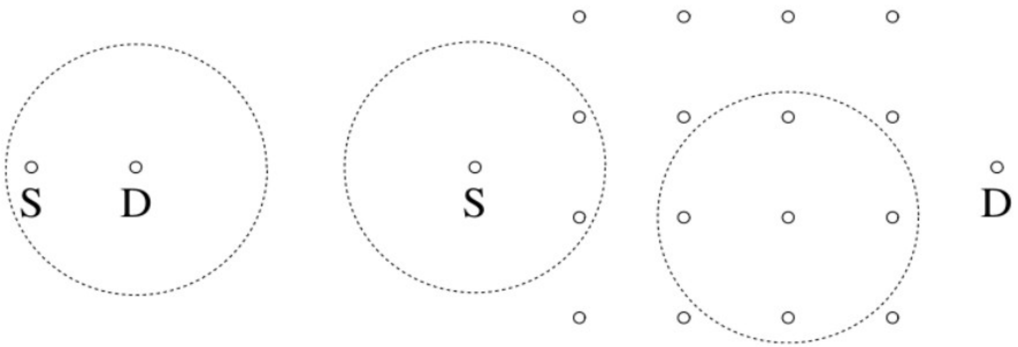
Method

- Peak Signal to Noise Ratio (PSNR) measures distortion between the received video and the original
- Structural Similarity (SSIM) quantifies loss of image structural information; it uses sliding windows shifted pixel by pixel on each single frame
- Jitter is the variation of end-to-end delay between packets

- Nano-sim patch, Qoe patch, and nanovideo streaming application available:
  - http://eugen.dedu.free.fr/publi/nanovideo/

Method

- We used two network topologies for the tests:
  - The first has two nodes, and is used to check the simulator with the two modules (QoE monitor and Nano-Sim)
  - The second has one source, one destination and 16 relays, and is used to discover how communication is done in a multi-hop nanonetwork
- The video file used as input is the classical “news” sequence in CIF resolution



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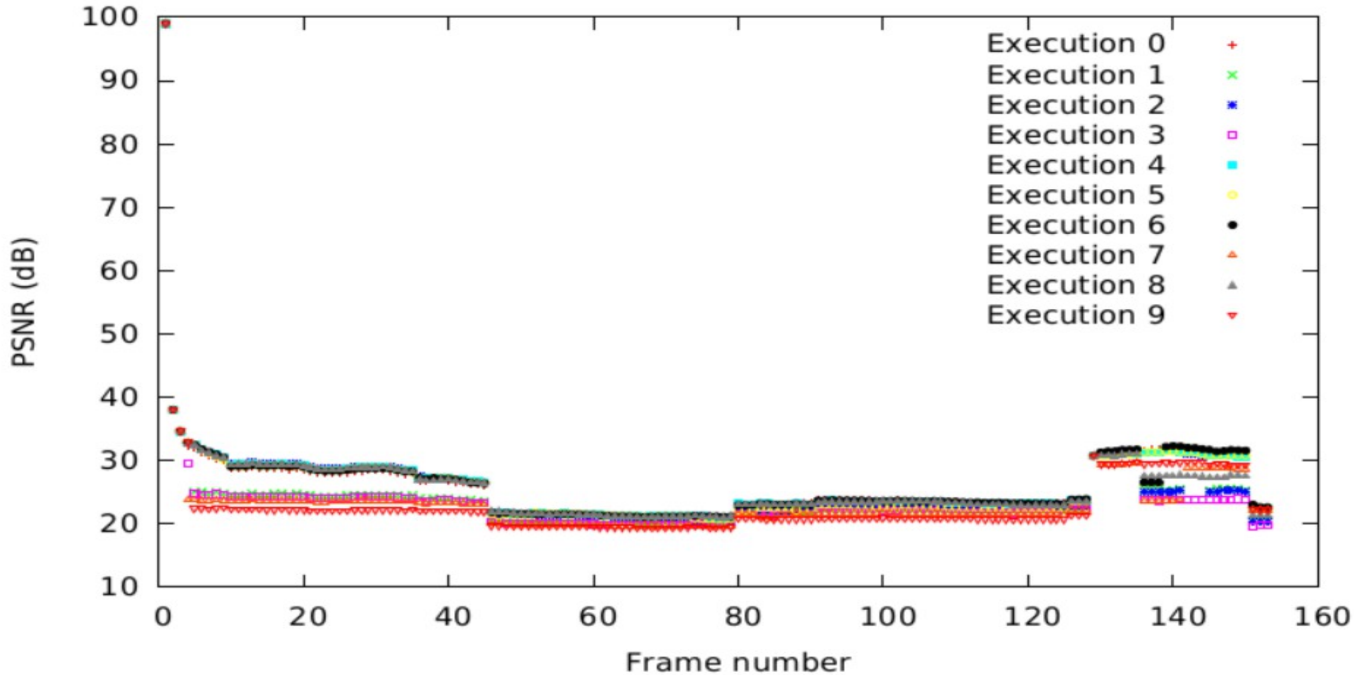
Simulation Result

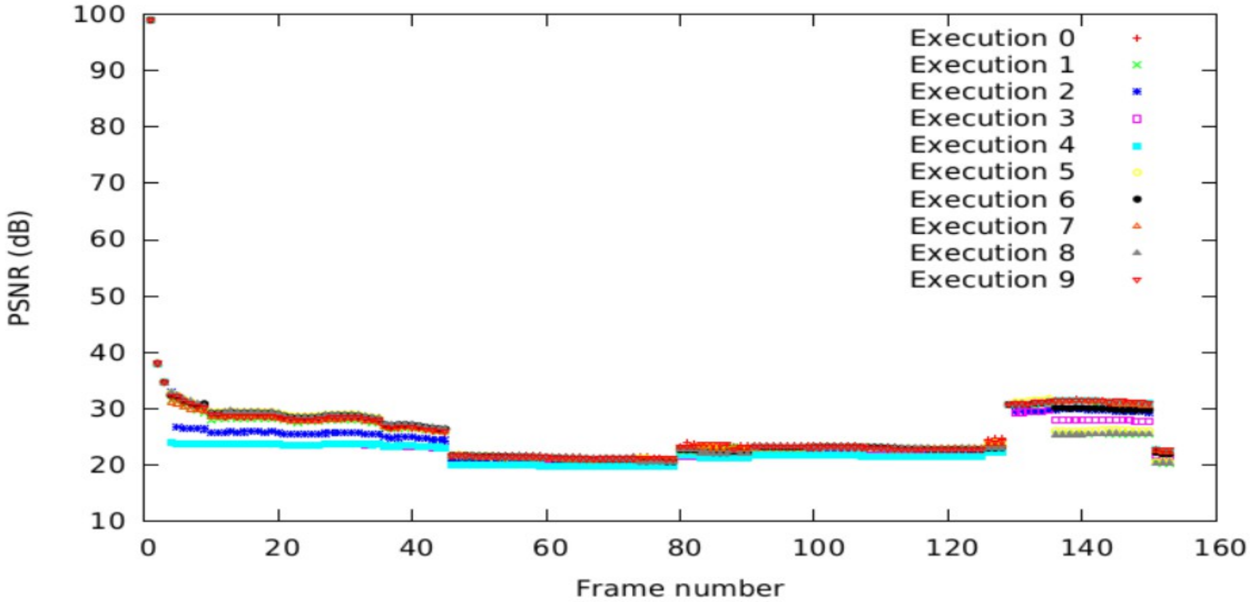
•The PSNR has a relatively low value (20 to 35 dB) and is quite regular
•No packet is lost on the network; but the reordering done by NanoSim, makes QoE monitor drop packets at receiver



The PSNR for 2-nodes network.

Simulation Result

•The abrupt changes in PSNR plot, appearing at frames 45, 80 and 130, correspond to abrupt scene changes in video file
•The PSNR for 18-nodes network, is similar to the one for 2-nodes and exhibits the same properties



The PSNR for 18-nodes network

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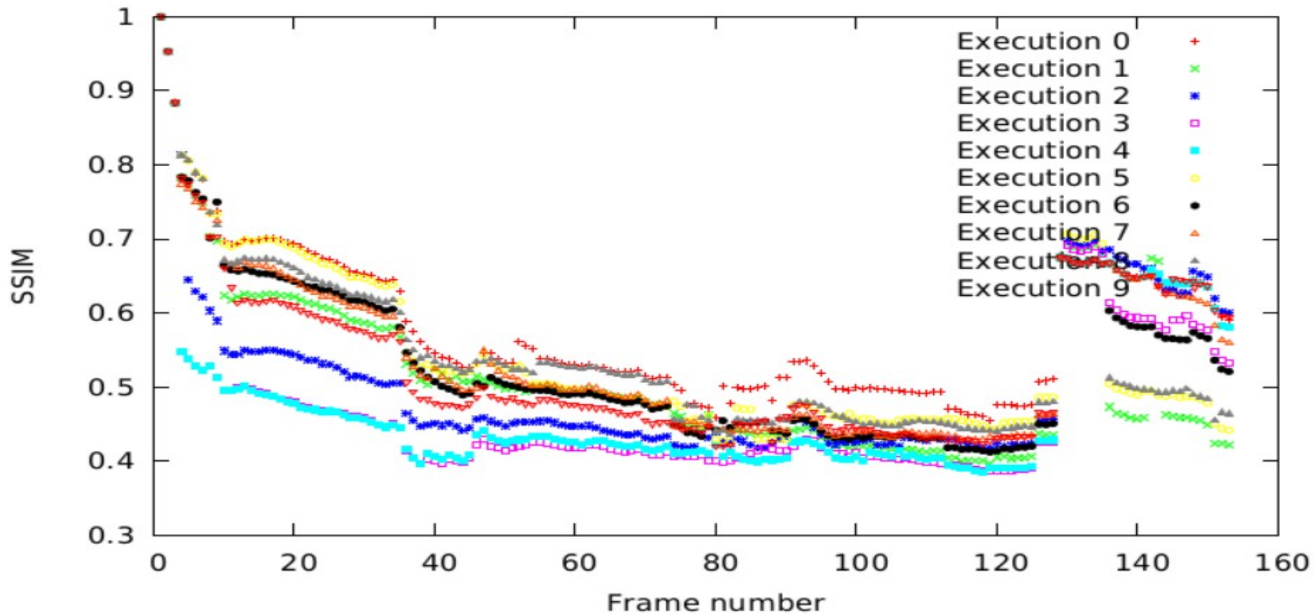
Simulation Result

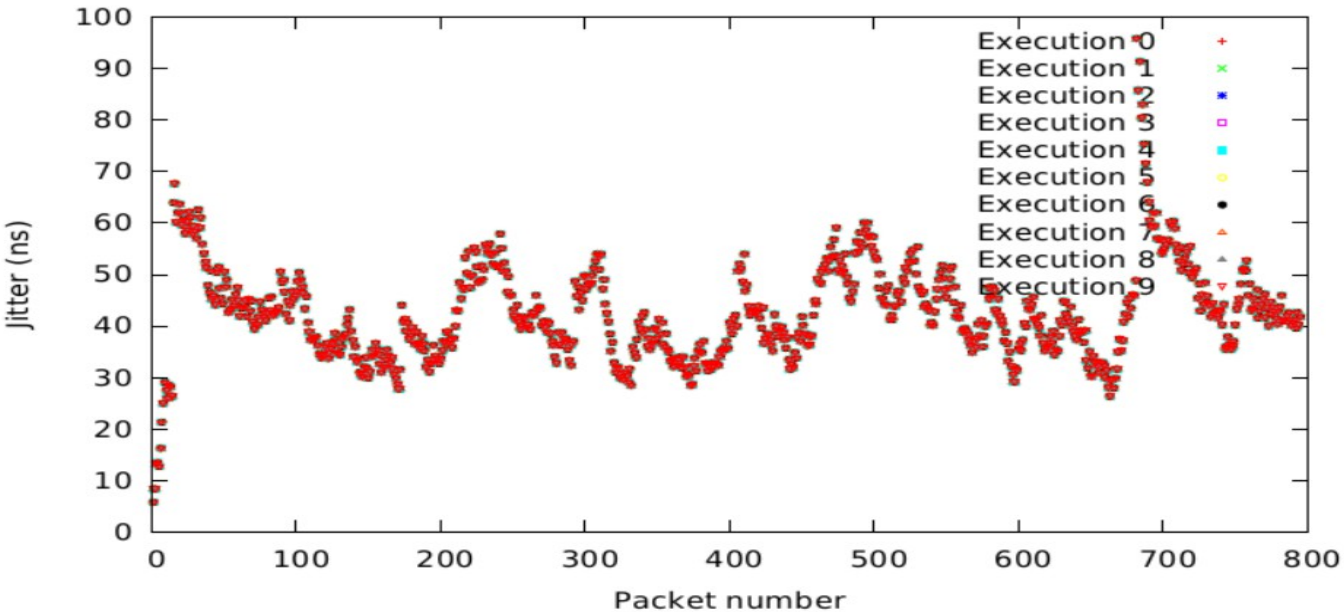
- SSIM curve varies more at abrupt scene changes, but it is less visible, except for frame 130
- The SSIM curve for 2-nodes network is similar to 18-nodes network



The SIMM for 18-nodes network

Simulation Result

- Jitter varies generally between 30 ns and 70 ns. These values are 3 orders of magnitude lower than what is currently found on Internet, which are of order of tens of ms
- As a consequence, the buffers at receiver side could potentially be much smaller than the ones on Internet



The jitter for 2-nodes network

Conclusion & Future Works

- Current simulation showed the limitation of the tools and their models. Unordered packets provide non realistic simulation

- Research in this field needs better tools and models for such studies

- Such a tool should take into account channel contention, transmission delays, a more realistic packet loss pattern, allow to read and write video files even at high bitrates, and, last but not least, give reliable results

Conclusion & Future Works

- Find methods for specific nanowireless channel coding for multimedia
- Take advantage of low-weight coding for multimedia content
    - Increase the proportion of “O” in the media
    - Minimize the interferences between different senders/receivers
    - Enhance energy consumption of the whole system

References

[1]	J. M. Jornet and I. F. Akyildiz, "The Internet of Multimedia Nano-Things," Nano Communication Networks (Elsevier) Journal, vol. 3, no. 4, pp. 242-251, December 2012
[2]	P. Wang, J. M. Jornet, M. G. A. Malik, N. Akkari, and I. F. Akyildiz, "Energy and Spectrum-aware MAC Protocol for Perpetual Wireless Nanosensor Networks in the Terahertz Band," Ad Hoc Networks (Elsevier) Journal, vol. 11, no. 8, pp. 2541-2555, November 2013
[3]	I. F. Akyildiz and J. M. Jornet, "Electromagnetic Wireless Nanosensor Networks," Nano Communication Networks (Elsevier) Journal, vol. 1, no. 1, pp. 3-19, March 2010
[4]	G. Piro, L. A. Grieco, G. Boggia, and P. Camarda. Nano-sim: Simulating electromagnetic-based nanonetworks in the network simulator 3. In Proceedings of the 6th International ICST Conference on Simulation Tools and Techniques, SimuTools ’13, pages 203–210, ICST, Brussels, Belgium, Belgium, 2013
[5]	D. Saladino, A. Paganelli, and M. Casoni. A tool for multimedia quality assessment in NS3: QoE Monitor. Simulation Modelling Practice and Theory, 32:30–41, Mar. 2013