NaNoNetworking Center in Catalunya (N3Cat)

Graphene-enabled Wireless Communications

About N3Cat
Research interests
N3Cat in CATGRAPHNET

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**The initiative**

Nanotechnology is enabling the development of devices in a scale ranging from one to a few hundred nanometers, which are able to perform simple tasks such as computing, data storing, sensing and actuation.

By means of communication, these nano-devices will be able to achieve more complex tasks and cover larger areas.

However, classical communication paradigms need to be revised/rethought before being used in the nanoscale.

The NaNoNetworking Center in Catalonia (N3Cat) has been created with the main goals of carrying fundamental research on communications among nano-devices, and educating and training the new generation of students in this field.
About N3Cat

Director: Prof. Ian F. Akyildiz
Academic staffs: 6      Students: 8 - 10

Current members

Broadband Wireless Networking Lab. (GeorgiaTech)
- Ian F. Akyildiz (Honorary Professor with the UPC and Director of N3Cat)

Computer Architecture Dept. (UPC)
- Josep Solé-Pareta and Albert Cabellos-Aparicio

Electronic Engineering Dept. (UPC)
- Eduard Alarcón-Cot and Ramon Bragós

Electrical & Electronics Engineering Dept. (Koç University)
- Özgür B. Akan
About N3Cat

Key research topics

**Molecular Communications**
- Use biological elements as blocks or design patterns (Information encoded inside molecules)

**Graphene-enabled Wireless Communications**
- EM based communications at the nano scale
Research interests

Molecular Communications

- Very efficient power consumption
- Bio-compatibility
- Already existing elements
- New approach in ICT field

CATGRAPHNET (Catalan Graphene Network) Kick-off meeting

5/20/2011
Research interests

Graphene-enabled Wireless Communications

- Wireless Nanosensor Networks
- Wireless Networks-on-Chip
- etc.
Research interests

**Common problems:**
- Channel modeling
- Scalability
- Nano-network architectures
- Performance evaluation by simulation

**In progress activity**
- [http://www.n3cat.upc.edu/](http://www.n3cat.upc.edu/)
Potential applications of graphene

Composites  Chemistry

Nano-optics  Nano-electronics

Bio-medicine  ¿Wireless communications?
Graphene-based nano-patch antennas show novel properties, different from metallic antennas. These quantum effects are envisaged to enable wireless communications at the nanoscale.

EM waves propagating in graphene-based nano-antennas have a lower propagation speed than in metallic antennas.

\[ v_{pnq} = c \]

\[ v_p = \frac{1}{\sqrt{LC}} \]

- \( v_p \): wave propagation speed
- \( c \): speed of light
- \( W \): antenna width
- \( L \): distributed inductance
- \( C \): distributed capacitance

\[ v_{pq} \propto \sqrt{W} \]
Why do we need a low propagation speed?

Let’s consider a 1 µm-long nano-antenna

- **Metallic antenna**
  
  \[ v_p \approx 2 \cdot 10^8 \text{ m/s} \quad \rightarrow \quad f = \frac{v_p}{2l} \approx 100 \text{ THz} \quad \rightarrow \quad \text{optical domain} \]

- **Graphene-based antenna**
  
  \[ v_p \approx 2 \cdot 10^6 \text{ m/s} \quad \rightarrow \quad f = \frac{v_p}{2l} \approx 1 \text{ THz} \quad \rightarrow \quad \text{electromagnetic domain} \]

**THz band**

- \( v_p \): wave propagation speed
- \( f \): antenna resonant frequency
- \( l \): antenna length
First resonant frequency of a graphene-based nano-patch antenna as a function of the nanoribbon width.

Graphene-based nano-antennas radiate EM waves in the terahertz band.

We need to study the properties of the terahertz channel at the nanoscale.
- Path loss
- Noise
Terahertz channel

Molecular absorption

\[ A_{abs} = \frac{1}{\tau} = e^{k(f)d} \]

\[ T_{mol} = T_0(1 - \tau) = T_0 - e^{-k(f)d} \]

Applications

Wireless Sensor Networks at the nanoscale: Wireless Nanosensor Networks

Health monitoring

Internet of nano-things

Enabling Electromagnetic Communication among Nanosensor Devices (ELCONA)

To design, simulate, manufacture and measure novel graphene-based nano-antennas

To provide a physical channel model for THz-band communications at the nanoscale and validate it experimentally

To develop a network architecture for Wireless Nanosensor Networks based on these antennas

Enabling Electromagnetic Communication among Nanosensor Devices (ELCONA)

- Project submitted to the ICT FET-Open call
- Currently in the second stage (full proposal just submitted)

Consortium partners

- Nanonetworking Center in Catalunya – UPC (Spain)
- Sineurop Nanotech GmbH (Germany)
- University of Wuppertal (Germany)
- Royal Institute of Technology – KTH (Sweden)
- Koc University (Turkey)
- Phantoms Foundation (Spain)
Theory of scalability for Graphene-based Wireless Communications at the nanoscale

Study how metrics scale

- Channel capacity
- Transmitted power

without quantum effects (metal)

with quantum effects (graphene)

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Graphene-based nano-antennas enable wireless communications at the nanoscale

- Antenna size in the order of 1 μm
- Radiation at the THz band

Graphene-enabled wireless communications will be radically different from current ones

- Classical communication paradigms and techniques need to be revised

Countless applications

- Wireless Nanosensor Networks
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