IoT in E-health: Challenges - Opportunities

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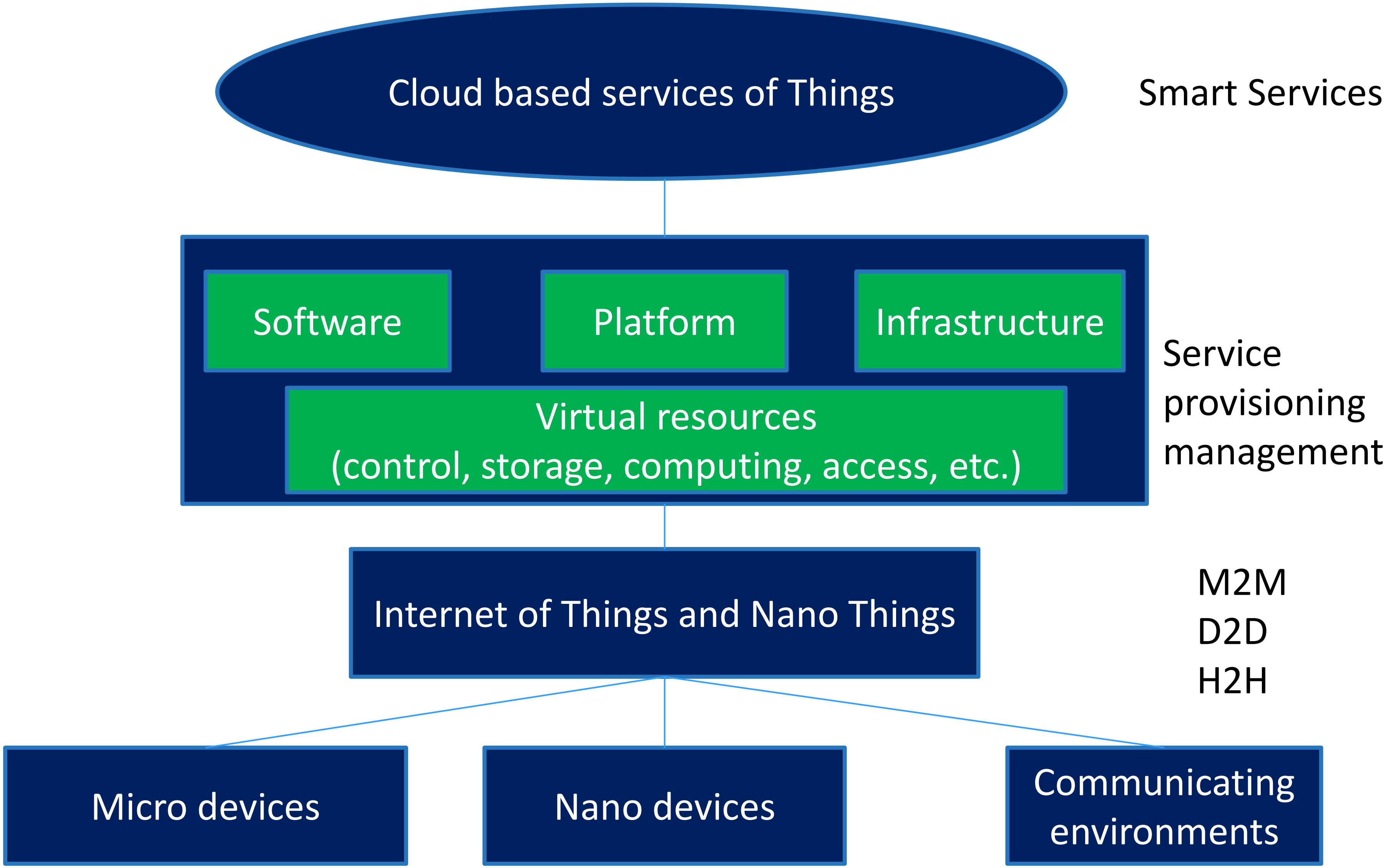
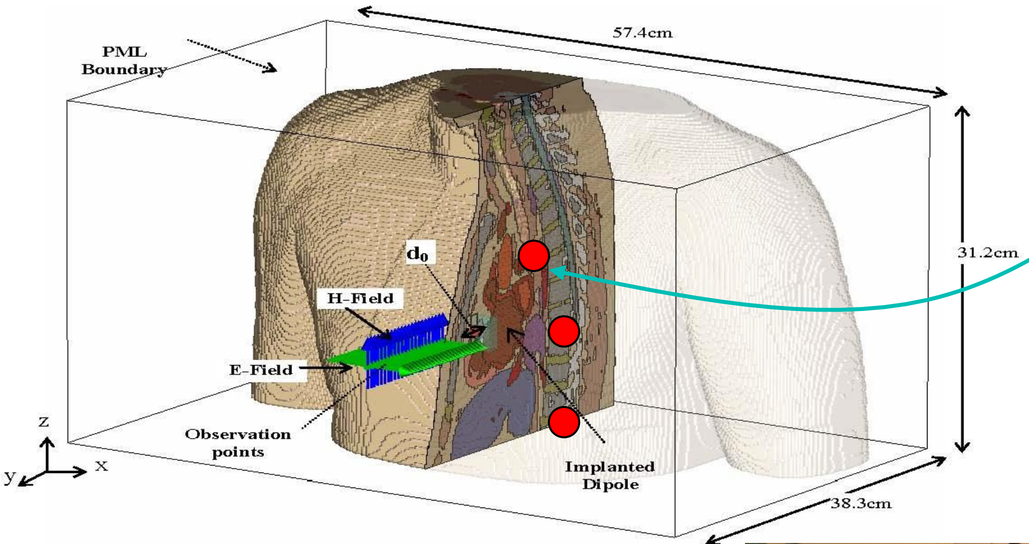

Cloud based services of Things
Smart Services
Software
Platform
Infrastructure
Virtual resources
(control, storage, computing, access, etc.)
Service
provisioning
management
Internet of Things and Nano Things
M2M
D2D
H2H
Micro devices
Nano devices
Communicating
environments

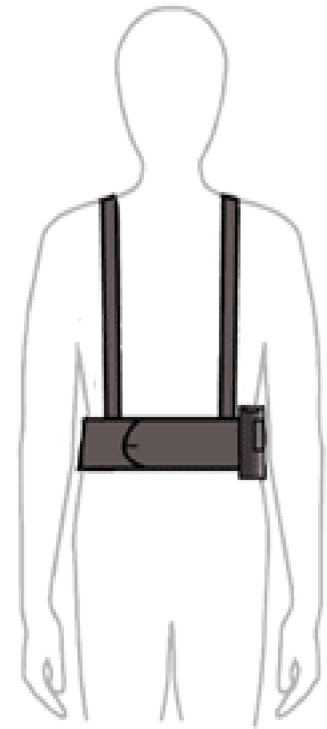
The Research Council of Norway

Medical Sensing, Localization and Communications (MELODY)

http://www.melody-project.info (2008-2015)

High Definition Video Capsule Endoscopy



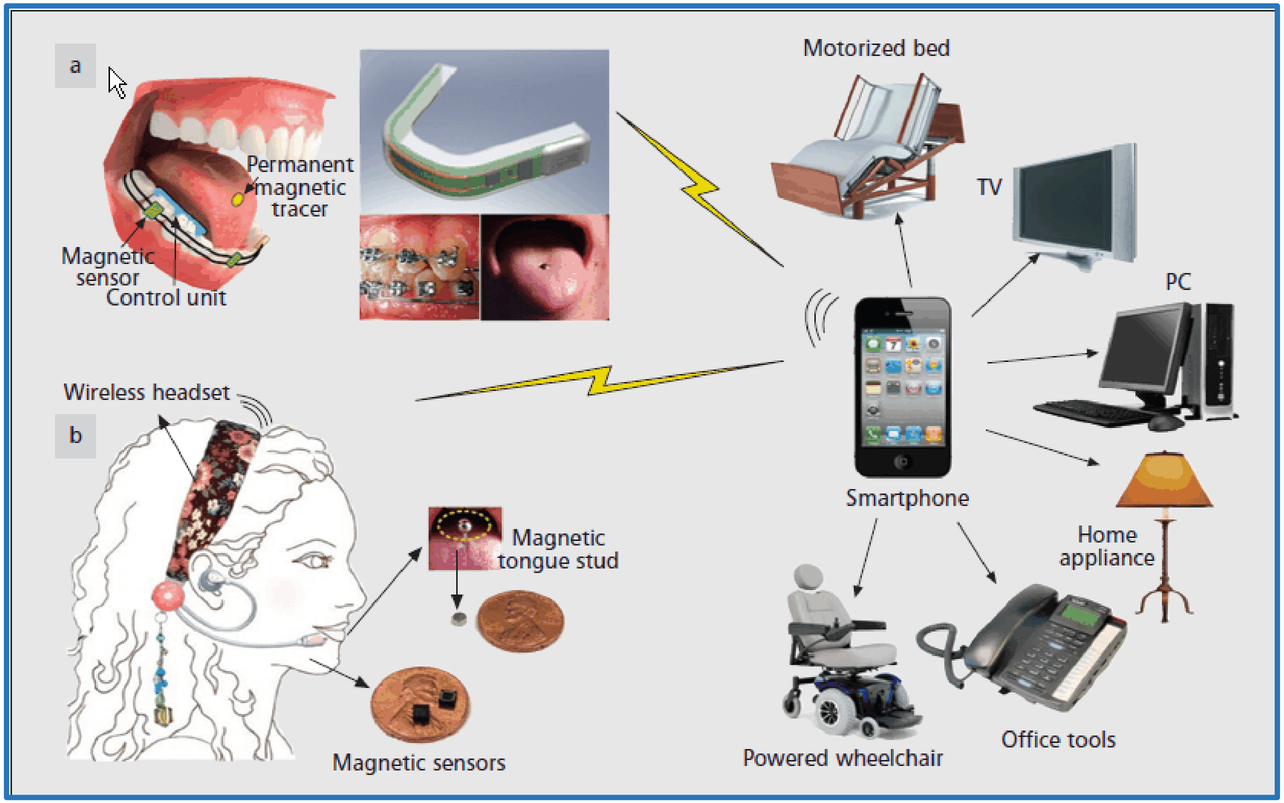


RecorderBelt
on Patient

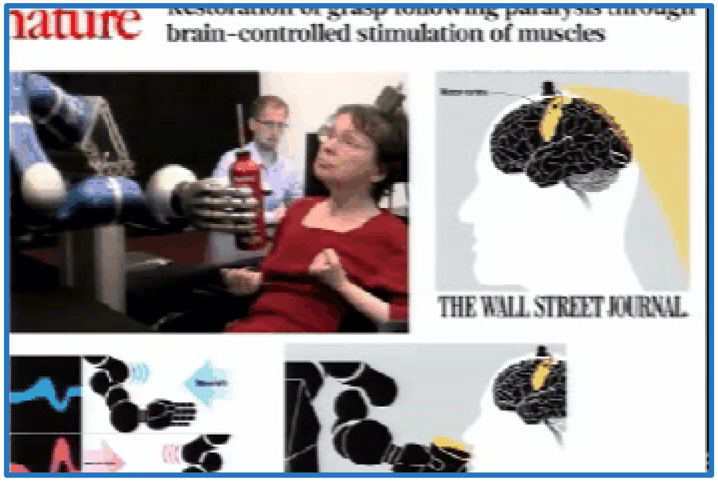
Blood sugar patch

AliveCor iPhone ECG

Accelerometer sensor

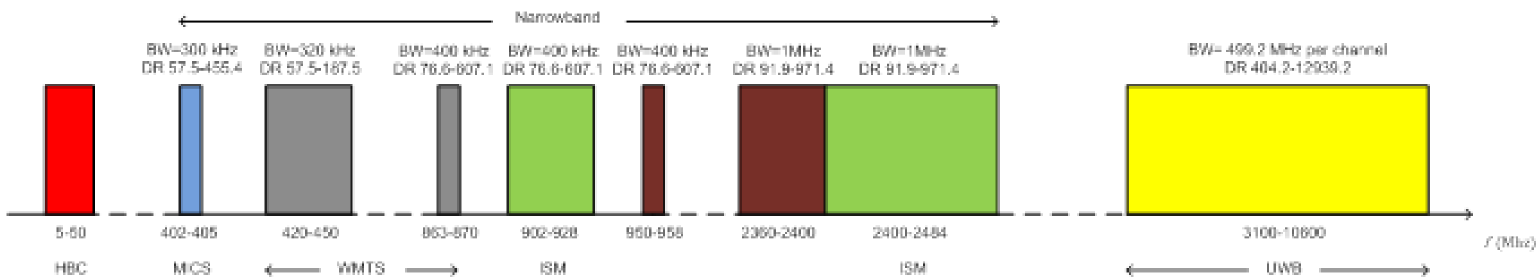


Tongue drive



Brain-computer-robotic controlled arm

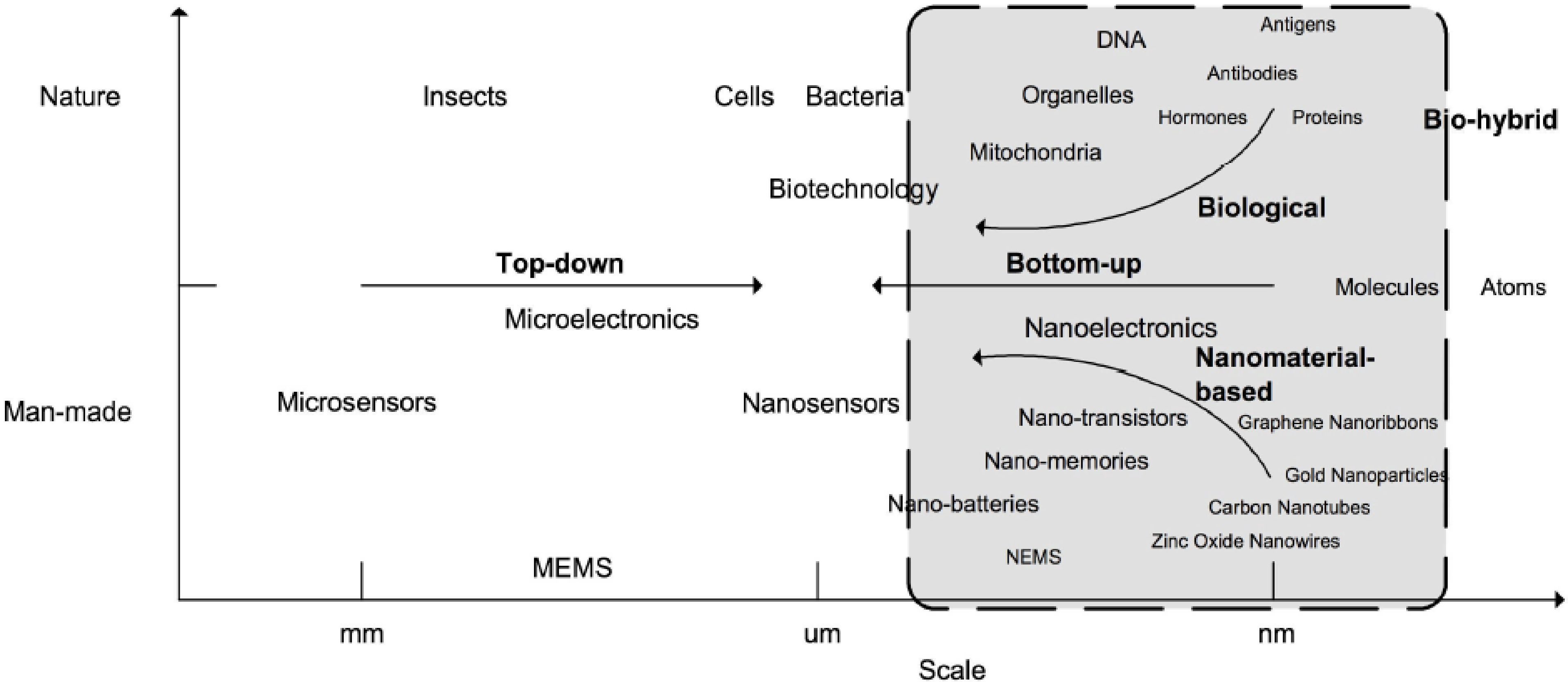
Frequency spectrum and bitrates



Application	Data rate	Power Consumption
ECG (12 leads)	288 kbps	Low
ECG (6 leads)	71 kbps	Low
Glucose monitoring	1600 bps	Very Low
SpO2	32bps	Low
WCE	>2Mbps	Low
WCE with VGA (640×480 pixel, 24 bits, 30 fps)	210.9 Mbps	Low
Blood Pressure	10 bps	High
Audio	1.4 Mbps	High
EMG	320 kbps	Low
EEG	43.2 kbps	Low
Neural Monitoring (for 512 sensors)	430 Mbps	Low

Future perspective

- Silicon technology era
  - is coming to an end (2030-2040)
- Molecular technology era
  - is starting and will be dominating our lives for next 80 years (2010 – onwards)

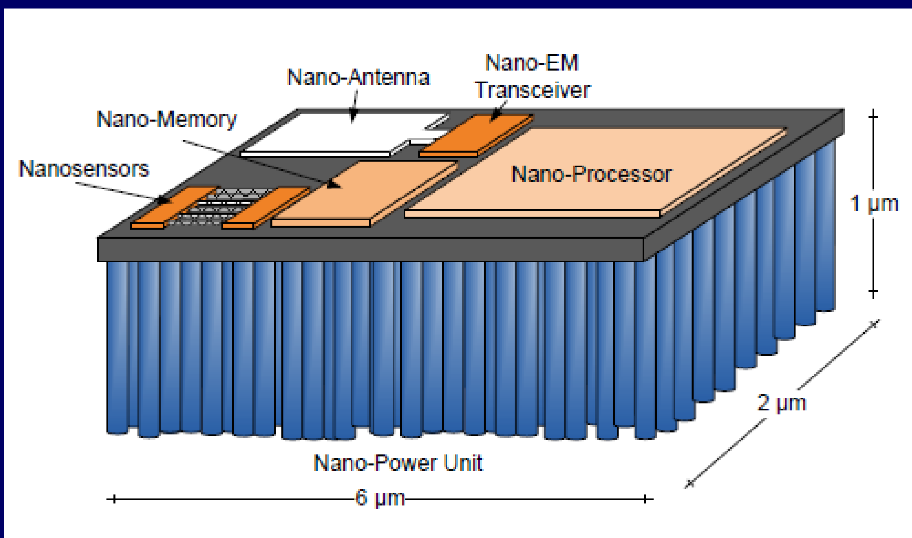


Nanomachine?

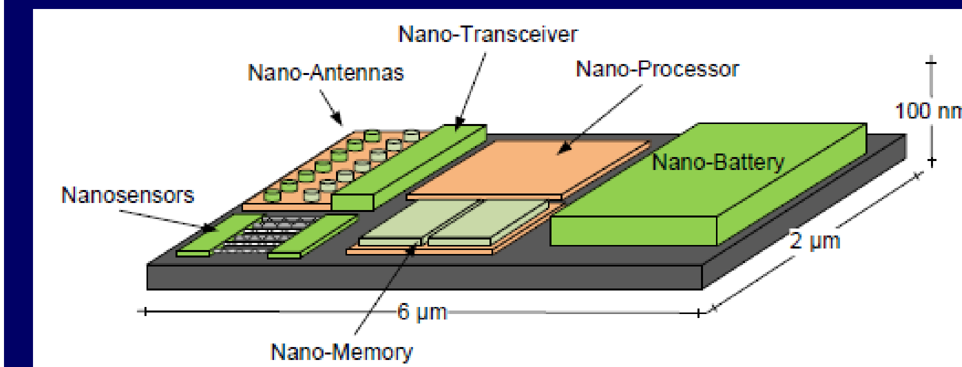
- **Definition:**
  - A device consists of nano-scale components, able to perform a simple specific task at nano-level
    - communicating, computing, data storing, sensing and/or actuation
- **Features:**
  - Self-contained
  - Self-assembly
  - Self-replication
  - Locomotion
  - Able to communicate in a cooperative manner for more complex tasks
- Applications:
  - Health status monitoring, diagnostics, targeted treatments, etc.
- **Two categories of nanomachines**
  - Biological nanomachines (molecular machines)
  - Nanomaterial-based nanomachines

Design principles

Nanomaterial Based Design



Bio-inspired Design



- Ultra low power design
- Extremely small footprint
- Highly specific, accurate, and stable sensors

- Better energy scavenging with hibernation
- Flexible structure – bendable
- Bio-compatible

Progress

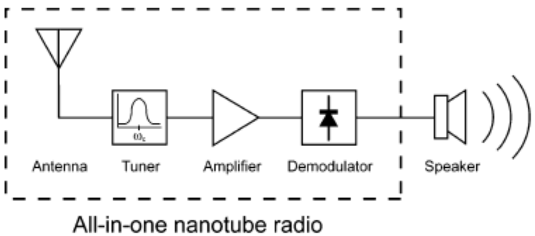
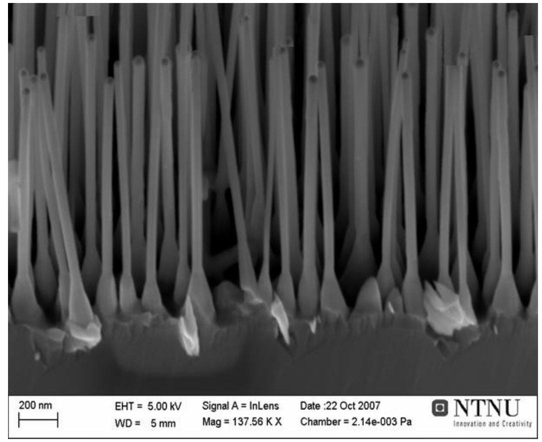
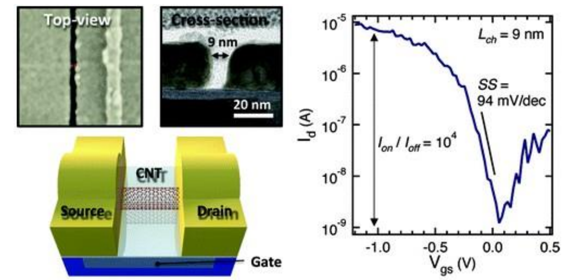


Figure 1. Block diagram for a traditional radio. All four essential components of a radio, antenna, tuner, amplifier, and demodulator may be implemented with a single carbon nanotube.

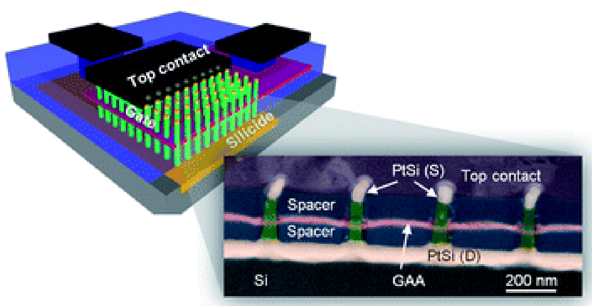
UC Berkeley 2007



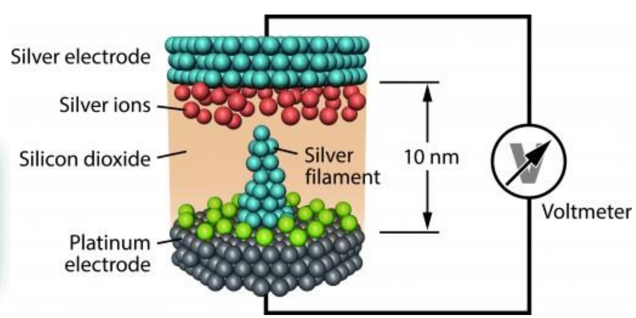
World first GaAs nanowires in graphene lattice, NTNU 2010



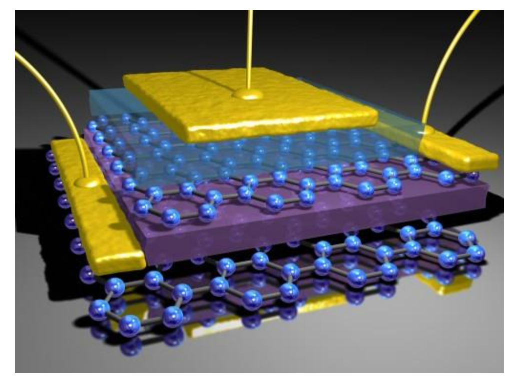
IBM's smallest nano transistor
700 – 1400 GHz. 2012



3D nanotransistors gate (red) surrounding
Vertical nanowires (gree)



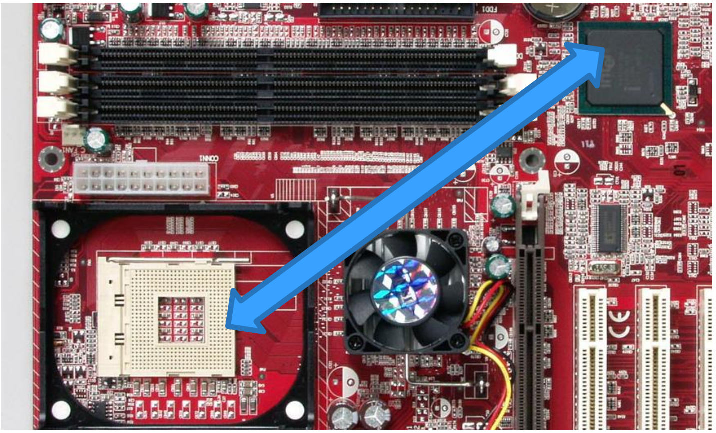
Nano batteries



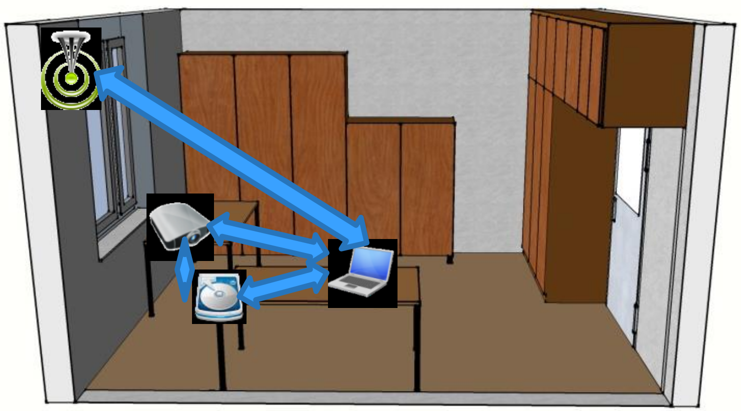
Nanotransistor based on two vertical graphene structures
FET Graphene Flagship, EU
(FET Human Brain Flagship, EU)

THz Band for Communications

- Nanonetworks: 300 GHz – 3 THz
- Drivers
  - Nanonetworks: Natural radiation of THz with **graphene** antenna
  - Wireless indoor for up to 0.5 Tbits/s



Chip-to-chip link



WLAN /WPAN

IEEE THz special interest group

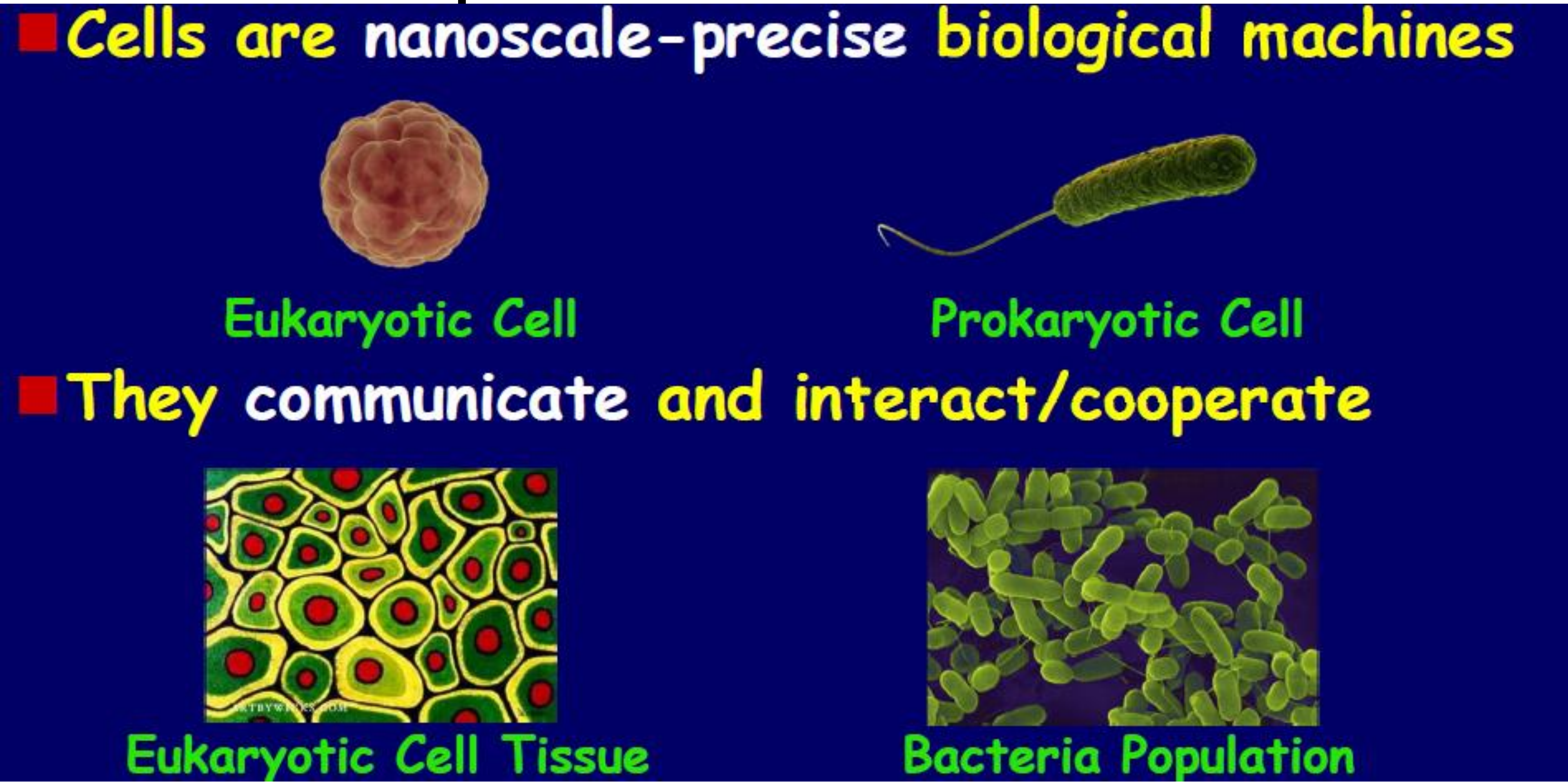
Comparison

	2.4 GHz 5 GHz	60 GHz	300 GHz
Data rates	600 Mbits/s	4 Gbits/s	100 Gbits/s
Bandwidth	40 MHz	2 GHz	10 … 100 GHz
Output powers (limitation)	22 dBm (regulation)	10 dBm (regulation & technology)	10 dBm (only technology)
Path loss at 10 m	ca. 60 dB	ca. 88 dB	ca. 101 dB
Antenna gains	ca. 3 dBi	15 - 25 dBi	20 – 40 dBi

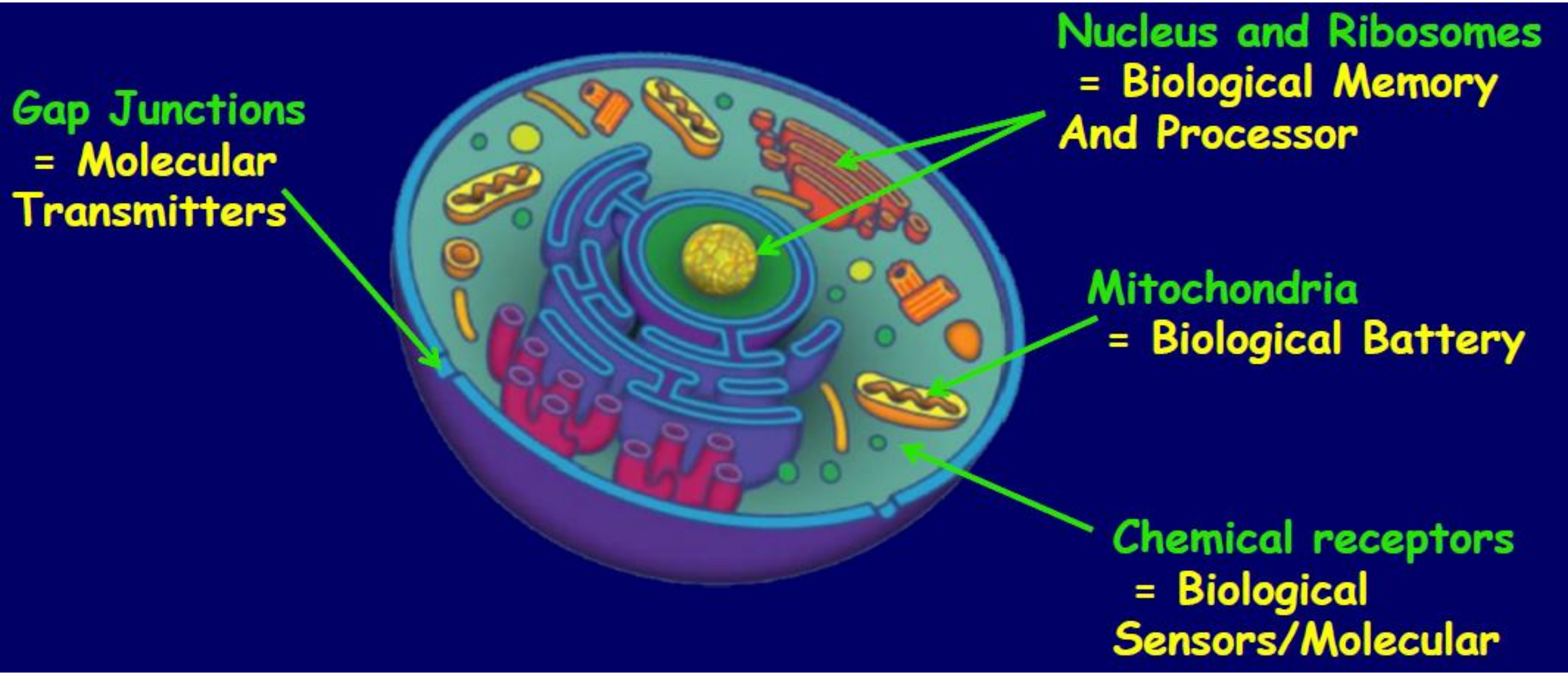
- Huge bandwidth
- Very high path losses
- Low output power

IEEE THz special interest group

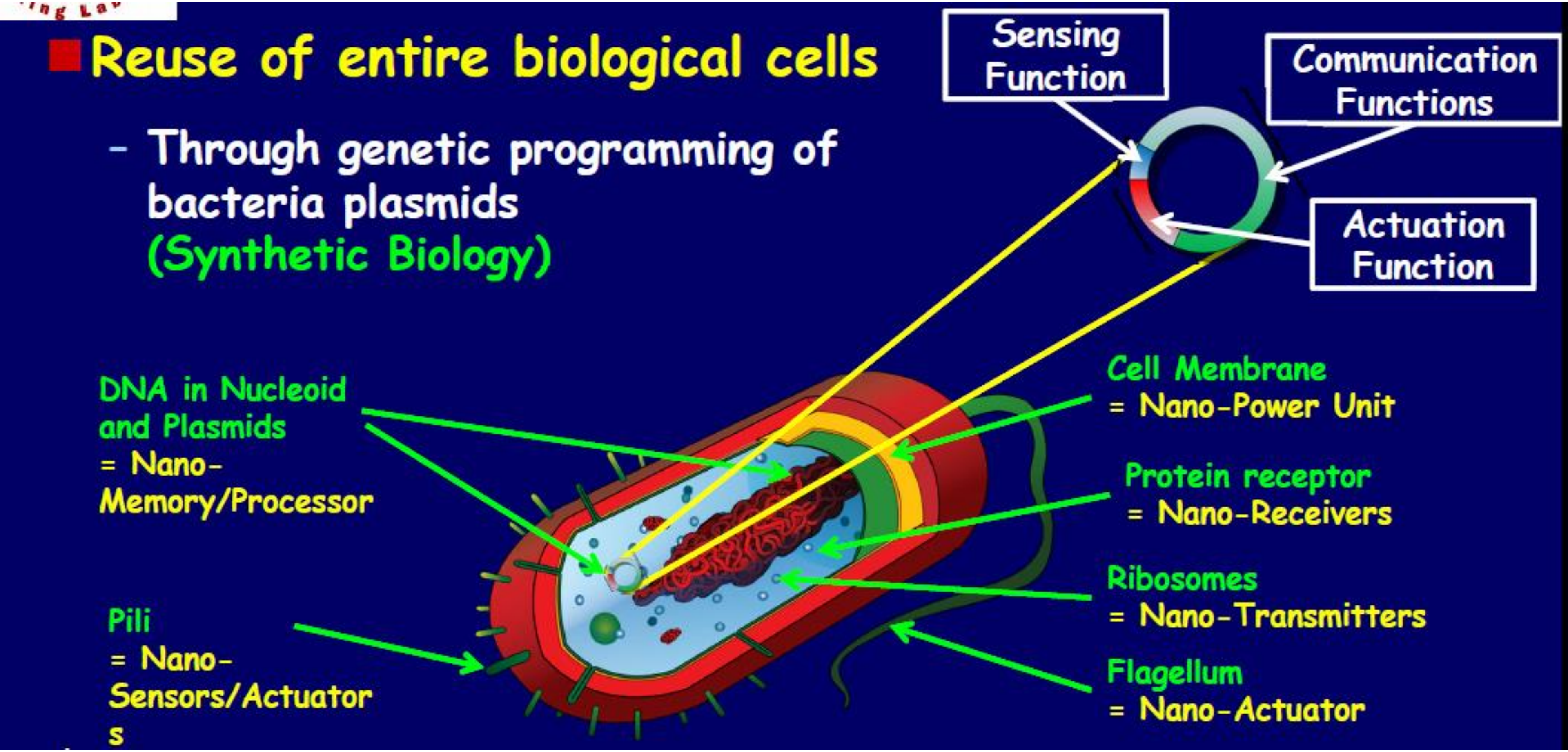
Biology: radically different



Cells as biological nanomachines



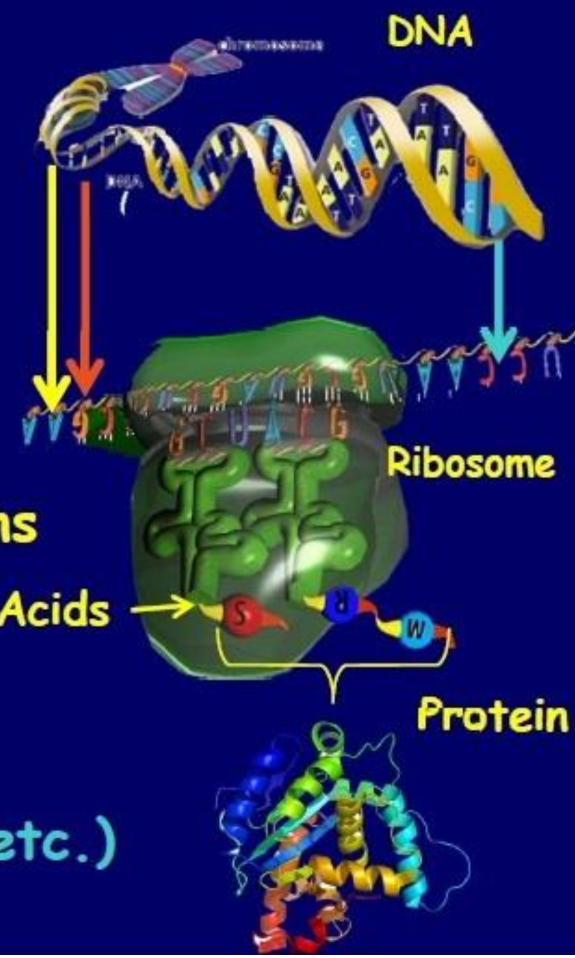
Bacteria-based nanomachines



Biobricks foundation (MIT) - http://biobricks.org

Biological memory and processor

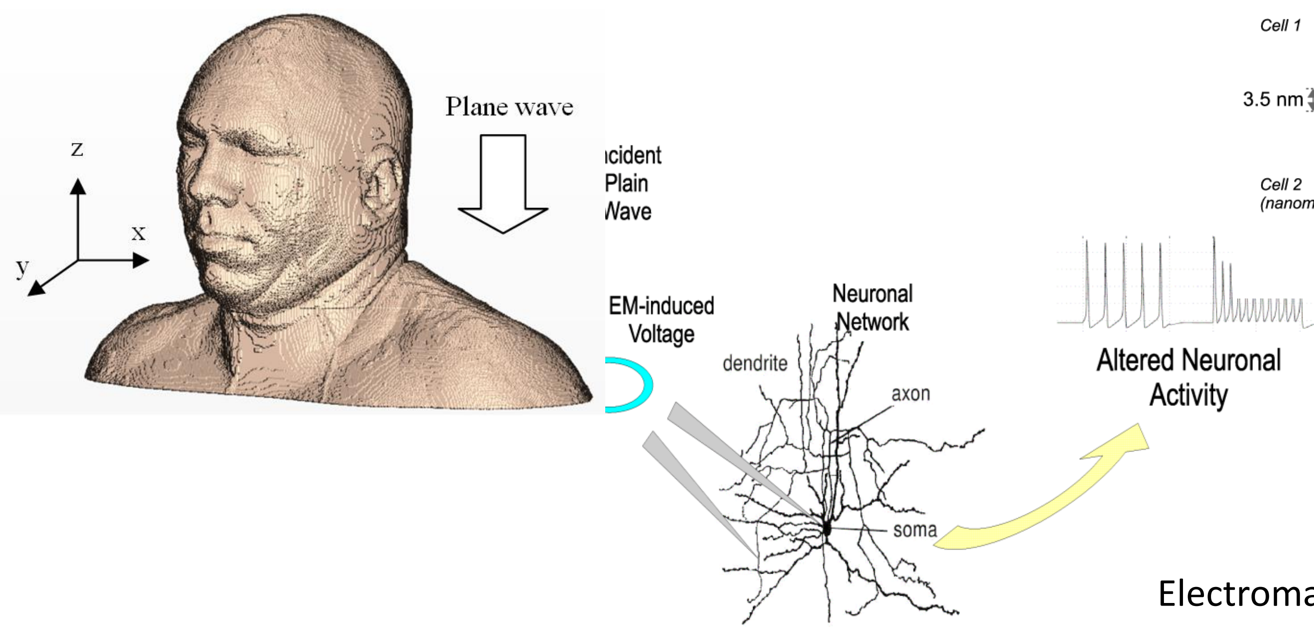
- DNA in the nucleus contains the information of protein structure (memory)
- Ribosomes read and process the DNA information (processor), synthesize the proteins
- Proteins control functionalities of the cell (e.g., cell signaling (Tx), ligand-binding (Rx), etc.)

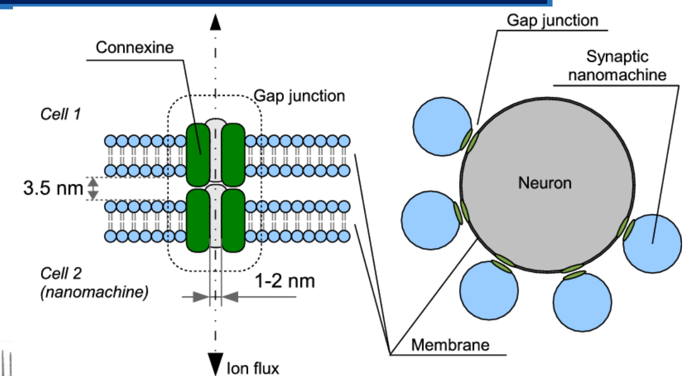


One gram of DNA can store 700 terabytes of data. That's 14,000 50-gigabyte Blu-ray discs!

Nanomachine-Neuronal Communication System

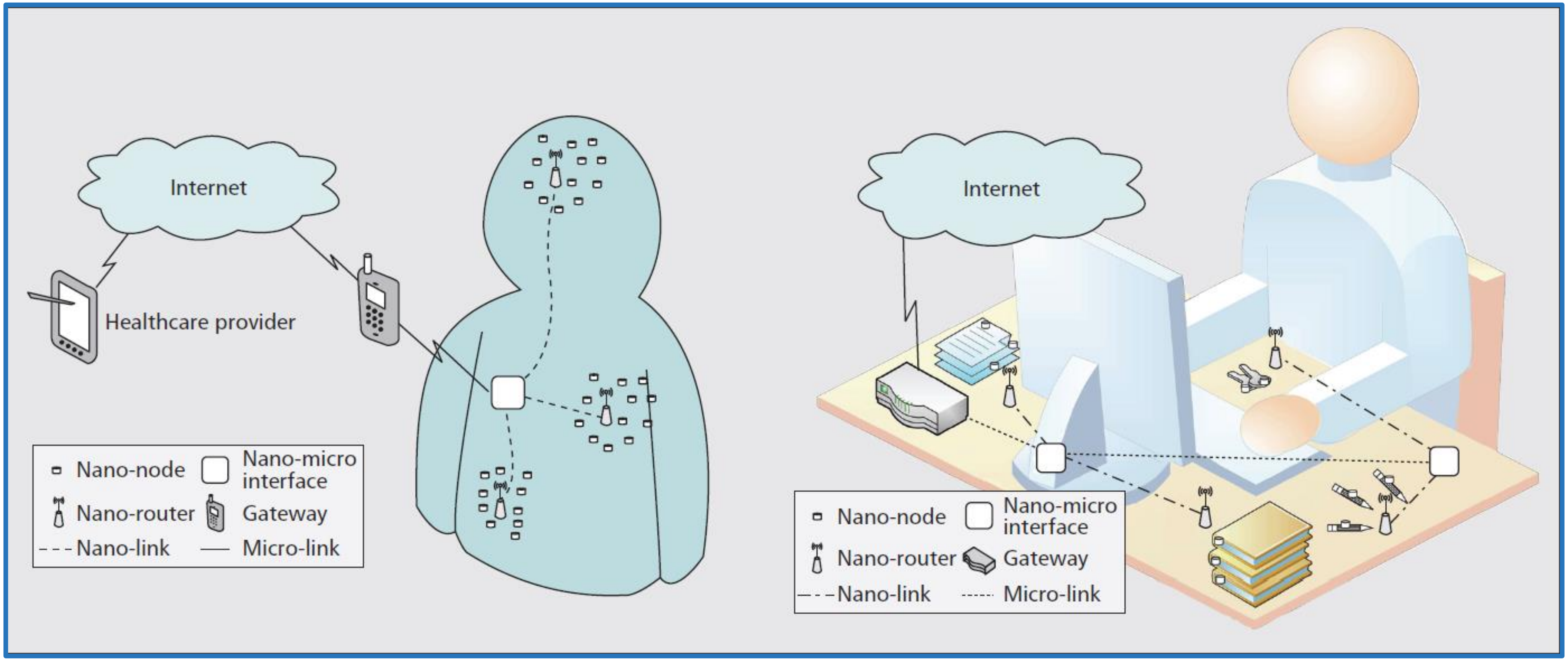
- Neuronal cells are considered part of a transmission system where the information is represented with *Action Potential* (AP) patterns propagating in the neuronal network.
- Computer simulations can be performed using a digital model in a single volume of tissue (*Voxel – volumetric pixel*).
- Extended NEURON simulator and data from the BigBrain project.





Electromagnetic-Neuronal transceiver

Micro-Nano Internet of Things

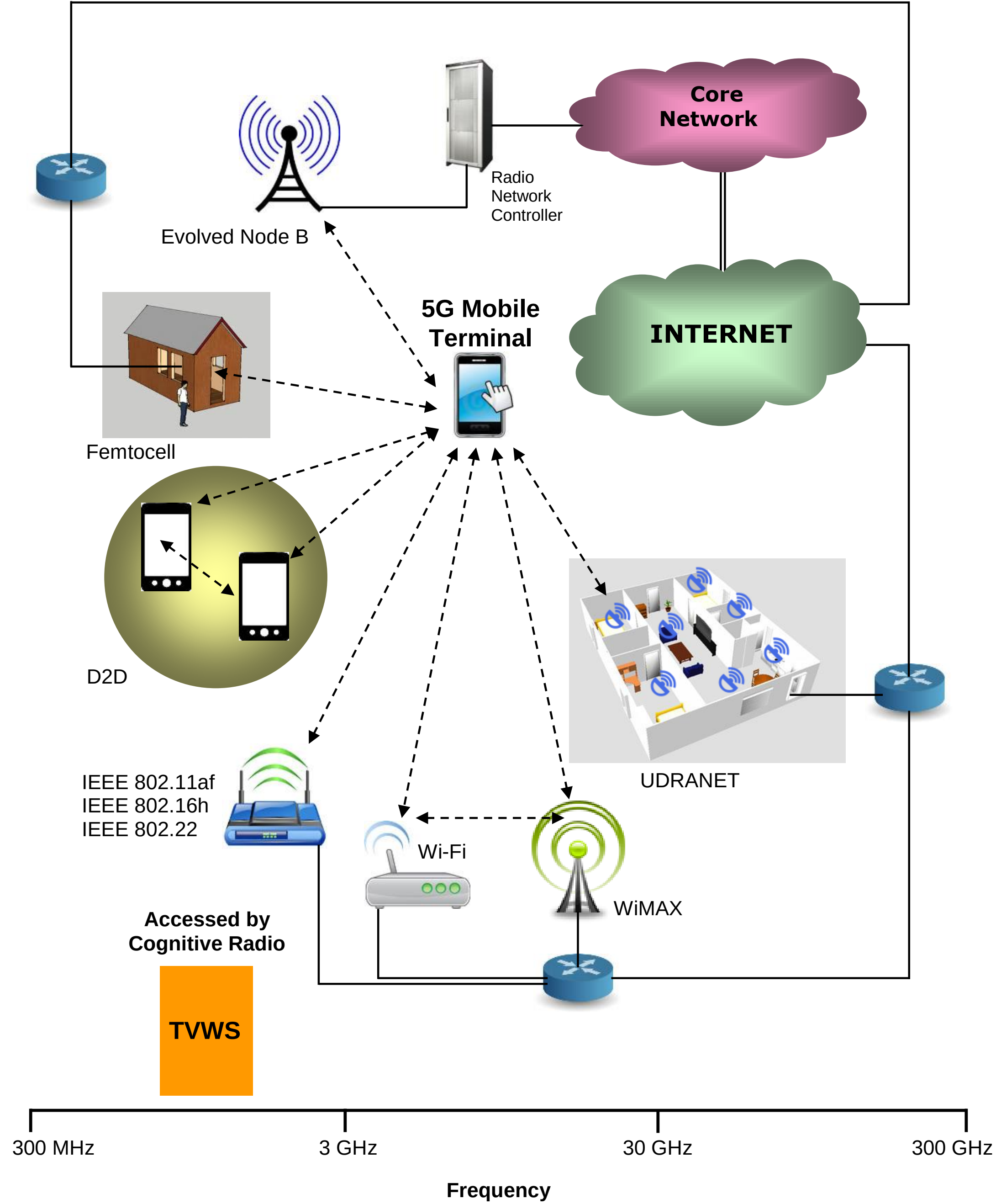


Network and service discovery challenges

- Network architecture
  - intrabody agents: DNA, bacteria, bio-graphene, etc.
  - nano-nodes: smallest and simplest nanomachines
  - nano-routers: comparatively larger computing resources
  - nano-micro interface devices: hybrid communication and computing devices
  - gateway: e.g., smartphone interfaces nano-micro devices
- Reliability and service discovery
  - end-to-end reliability: nano-node failure, transient/burst/absorption effects in molecular nodes
  - latency

High speed communication challenges

- Transceiver
  - antennas: graphene-plasmonic metamateral -> optical characteristics
  - frequency bands: mm-wave band, THz-band
  - modulation schemes: pulse based w/ 10^{-15} sec duration w/ PPM
  - coding for secure communications: : i) redundancy removal, ii) map from given data distribution to a uniform distribution, iii) chaotic map, and iv) simple encryption method
- Channel modeling
  - path-loss: biological environment – free space
  - noise: molecular absorption color noise, signal dependent noise)
  - bandwidth and channel capacity: large bandwidth -> Tbits/s
- Protocols
  - asynchronous MAC w/ simpler CSMA-CD
  - addressing: unique ID, DNA-logic
  - routing: multi-hop; network discovery and service


Core Network
Radio Network Controller
Evolved Node B
5G Mobile Terminal
INTERNET
Femtocell
D2D
UDRANET
IEEE 802.11af
IEEE 802.16h
IEEE 802.22
Wi-Fi
WiMAX
Accessed by Cognitive Radio
TVWS
300 MHz
3 GHz
30 GHz
300 GHz
Frequency