JUMP

Joint University Microelectronics Program

Proposers' Day Workshop

Monday, January 23, 2017

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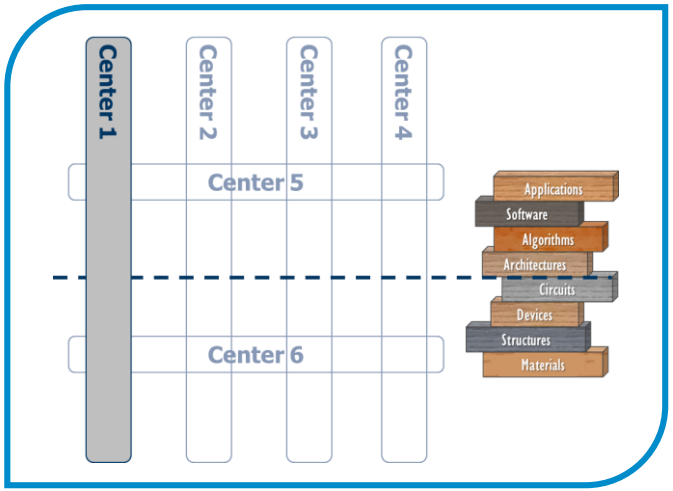
Joint University Microelectronics Program

RF to Terahertz Sensors and Communication Systems

Vertical Research Center



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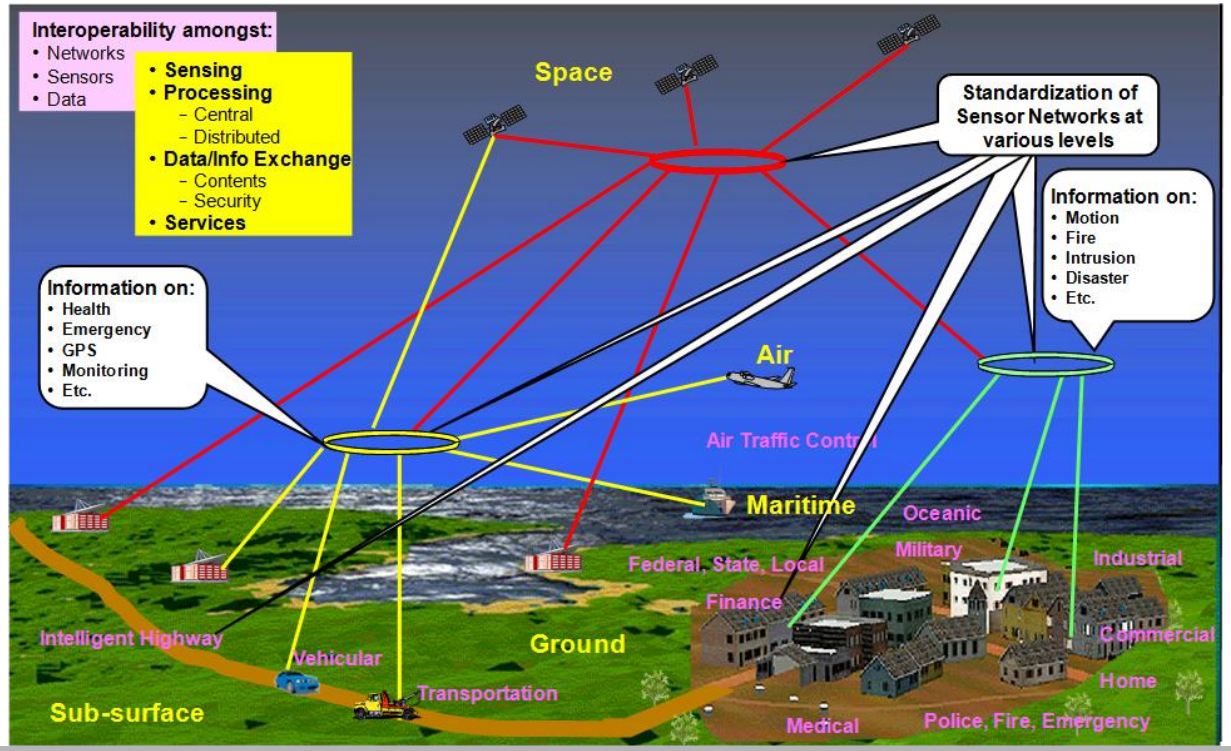
Advanced Microelectronics
Raytheon Company

Center Motivation

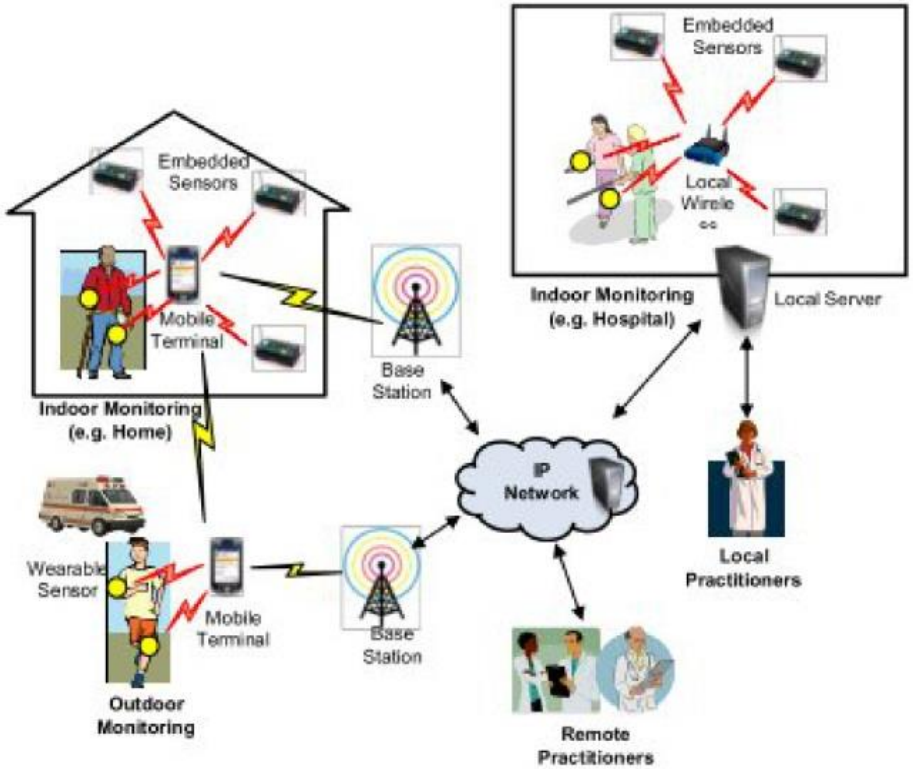
- Efficient use of Increasingly Crowded EM Spectrum for Sensing and Communicating
- Information Extraction for Enhanced Situational Awareness
- Higher level of functionality/per unit area/volume and Lower C-SWAP (Cost, Size, Weight and Power)



Future Sensor and Communication Systems: Energy Efficient, Autonomous, Secure (Private), Cost Effective Sensing, Extraction, Processing and Communication of Information

Center Research Vectors

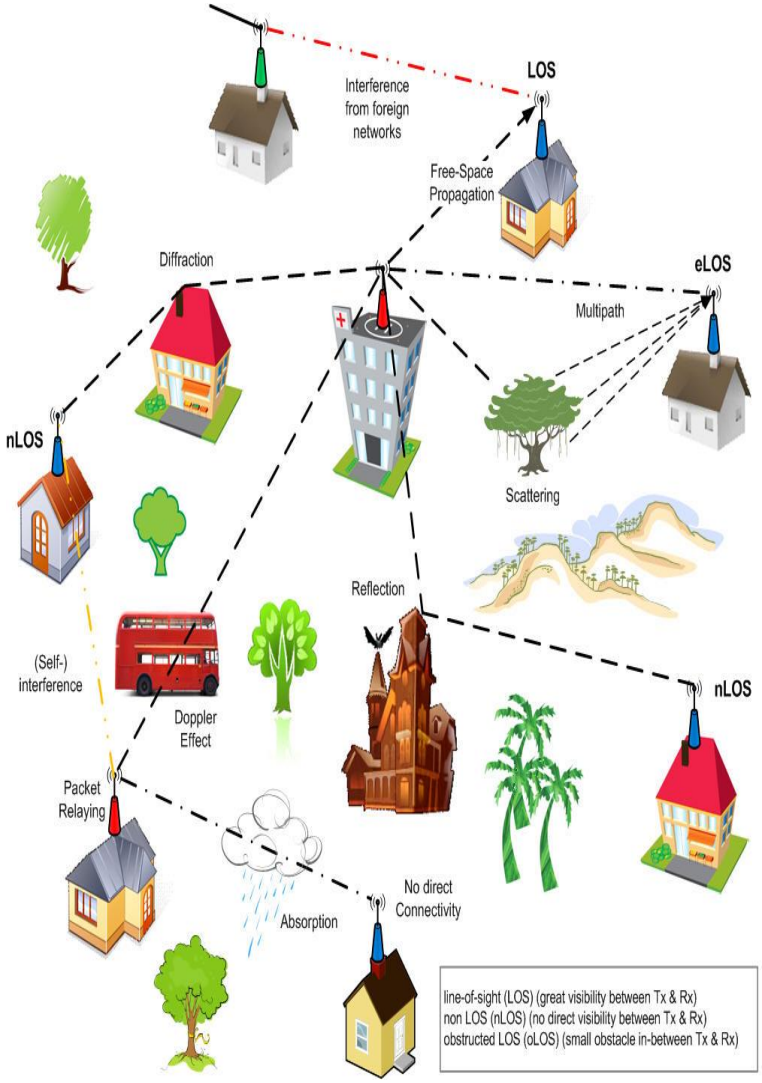
- This theme covers two general, synergistic application areas:
  - **RF Sensors**
  - **RF Communications Systems**
- These systems
  - Operate at microwave, millimeter wave or THz frequencies
  - Support consumer, military, industrial, scientific, and medical applications
- High-level system examples may include radar, communication, reconnaissance, and/or mmwave/THz imaging



Examples

It is envisioned that future

- **RF sensor systems** will
  - Adaptively sense their environment, extract/manipulate/process information, and autonomously react/respond to the information
- **Cognitive communication system** will
  - Operate in complicated radio environments with interference, jamming and rapidly changing network topology
  - Obtain (sense) information about their environment (aware of their environment and the available resources) and dynamically adjust its operation (e.g., efficient spectrum use, interference mitigation, spectrum prioritization) to provide required services to end users



Both examples require novel, energy-efficient devices, circuits, algorithms, and architectures

Center Research Elements (1)

Future Sensor and Communications Systems may require (but are not limited to):

- **Agility**: reconfigurable, adaptive, multi-function, multi-mode, self-calibrating sensors with increased degrees of freedom for efficient use of EM spectrum (including: spectrum agility, instantaneous bandwidth/ waveform agility, (very) wide bandwidth, high dynamic range).
- Compact, inexpensive **sensors** that can sense / measure multiple variables
- Coordinated use of **multiple sensor modalities**
- Collaboration of sensors and compute through **flexible and resilient architectures** and interface protocols
- Resilience, trust, privacy
- System level management of spectrum utilization to improve spectrum occupancy and allow **"smart" frequency allocation** (including non-contiguous band aggregation and use of new waveforms) and/or sharing to overcome interference (including self-induced) and jamming problems; (e.g., scan and detect transmission across very wide range of frequencies to avoid interference as well as to make efficient use of spectrum resources).

Center Research Elements (2)

Future Sensor and Communications Systems may require (but are not limited to):

- Scalable, **adaptive, behavioral learning and cognitive processing** (information extraction) architectures for real-time and reliable sensing, operation and communication (e.g., feature-driven "intelligent" sensing that achieves the ultimate energy efficiency by only detecting salient features/patterns/thresholds).
- Communication and reconnaissance approaches to mitigate threats and enable rapid transmit/receive critical data and constant streaming
- **Autonomous operation and decision making** (e.g., embedded real-time learning, ability to recognize threat scenarios, ability to do local-processing before transmitting the data/information). Autonomous operation also may require **integrated power generation/harvesting, distribution, control/regulation and modulation**.
- **Super-linear communication links** (enabling high modulation formats) and integrated communications components for IoT and distributed sensor systems that enable ultra-low power, high data rate, long-range sensor communications with high linearity in up/down conversion
- **In-sensor memory and compute**
- Large format (e.g., 3m x 3m) flexible smart sensors/sensor arrays

RF to THz Theme

- Requires **breakthrough vertically integrated research**
  - Principally aimed at **efficiently generating, modulating, manipulating, processing, communicating (transmitting) and sensing/detecting radiated signals**
- Research areas include but are not limited to
  - Materials
  - Devices, components
  - Circuits
  - Integration, packaging, connectivity,
  - Architectures (e.g., subsystems/arrays)
  - Algorithms
- Innovations must demonstrate **orders of magnitude enhancement** in at least one aspect of performance or appropriate proposer defined figure of merit without compromising other aspects
- Proposers are expected to define a **grand challenge** in the RF to THz Sensor and Communication Systems space that their Center will address

Possible Research Tasks (1)

In addition to the information outlined above, possible research tasks of interest include but are not limited to:

- **Novel materials** (semiconductors, packages, substrates, magnetics, metamaterials, etc.), **devices** (diodes, transistors, switches, varactors, etc.), **components** (High Q inductors, filters, low loss transmission lines, couplers, duplexers, antennas/radiating elements, etc.) and **associated fabrication processes and manufacturing methodologies** for realization of RF to THz circuits and systems.
- **Highly linear, high efficiency** (low power dissipation), (ultra) wide-bandwidth, ultra low noise **analog/RF devices and circuits** (e.g., PAs, LNAs, switches, mixers, IF amplifiers) with practical operating characteristics (e.g., reliable operation at room temperature or higher).
- **Breakthroughs in mixed signal and analog circuits** (e.g., high dynamic range, low power dissipation ADCs, DACs, etc.) including new approaches (circuits and architectures) for analog signal/information processing.
- **Agile** (adaptive / dynamically reconfigurable) RF devices, circuits and architectures including **self-optimizing** and resilient networks and **dynamically reconfigurable interconnect fabrics**

Possible Research Tasks (2)

In addition to the information outlined above, possible research tasks of interest include but are not limited to:

- New technologies (materials (metals, dielectrics), components (sources, detectors, propagation media, etc.,) and fabrication processes) and architectures to realize **(ultra) low loss, wide bandwidth interconnects/connectivity and communication links** that **dramatically reduce energy consumption** in communication or distribution of data/information
- Materials/devices/components/packaging for **extreme operating conditions** (e.g., high temperature) and **harsh environments**.
- Materials, devices, circuits, subsystems and approaches for package level or integrated (e.g., on-chip) **energy generation (harvesting), storage,** distribution and management/regulation.
- Material, devices, circuits, packaging, assembly, and systems for spectroscopy and **mWave and (sub)THz imaging** for DoD and commercial applications (e.g., for vital signs, security, non-invasive bio-signal and characteristic, etc.)

Possible Research Tasks (3)

In addition to the information outlined above, possible research tasks of interest include but are not limited to:

- Novel packaging and integration approaches including: **3D and heterogeneous integration** of diverse materials (e.g., Si, III-Vs, II-VIs, 2D material, magnetics, ferromagnetic, ferro-electric, multiferroics, etc.), devices and functions to improve performance, reduce cost, create new capabilities and/or increase functional density (e.g., fully integrated logic, RF and mixed signal functions)
- Novel circuits/architecture/algorithms for precision timing for sensor/communication system **operation in PNT (Positioning, Navigation, and Timing) denied environment**
- **Novel, energy efficient transceiver modules, subsystems, arrays and architectures** including: high power (high power density) mw to THz transmitters, receivers and communication links (e.g., massive yet scalable MIMO and beam formers).
- Development of rapid, accurate, multi-physics, multi-dimensional, multi-domain **(co-)design** (RF/analog/EM, thermal, mechanical) and **simulation tools and methodologies** for complex (e.g., 3D, heterogeneous) multi-function RF systems

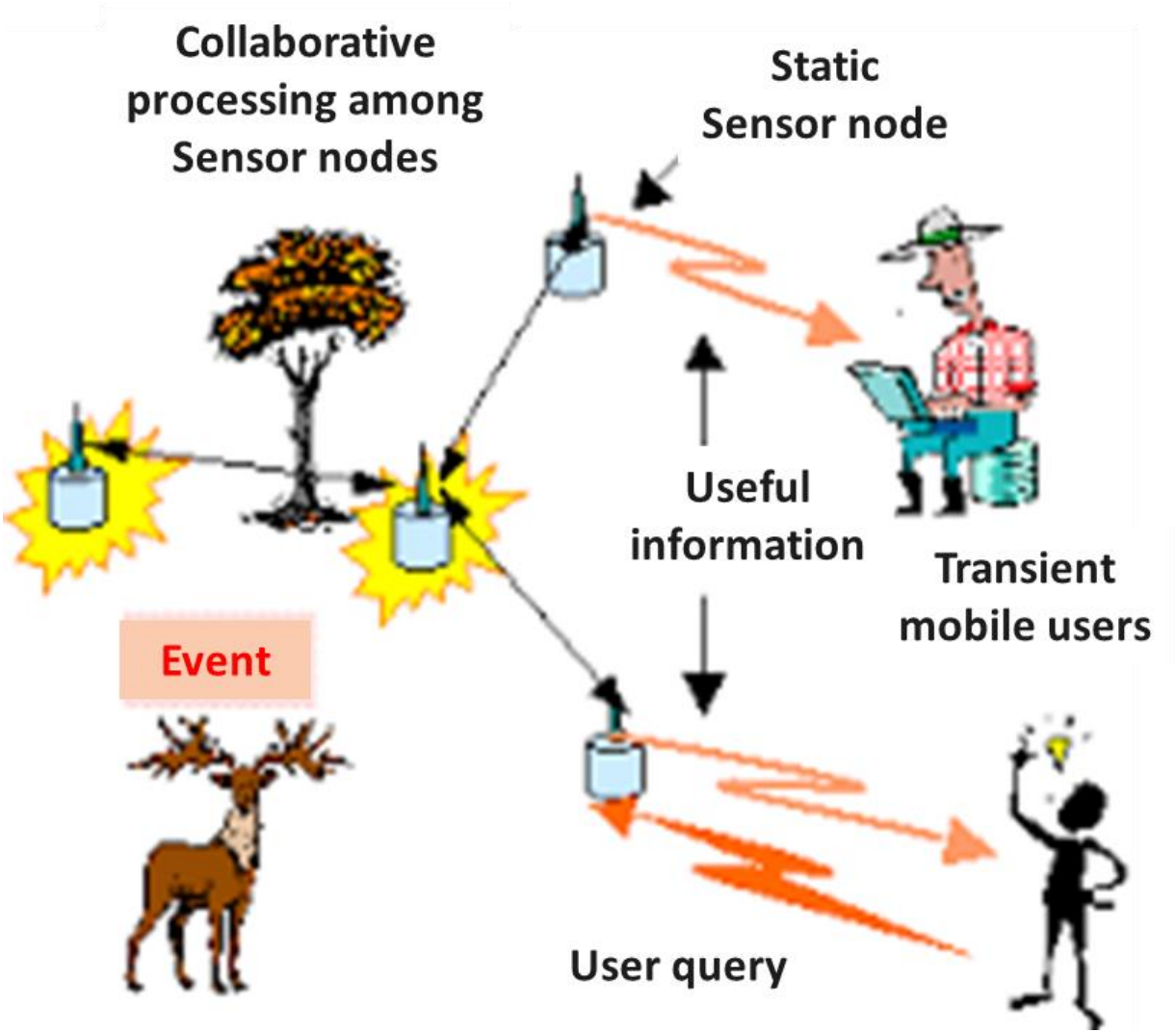
Degrees of Emphasis

While not limited to students from these disciplines, **students obtaining degrees** from the RF to THz Sensor and Communication Systems Center in the following areas of study are of particular interest to our sponsors in the years ahead:

MS / PhD in

- **Applied Physics**
- **Chemistry or Chem Eng.** (growth, synthesis, fabrication processes)
- **Electrical / Electronics Engineering or Electrical and Computer Engineering** (RF devices, circuits, systems, algorithms)
- **Material Science or Engineering** (synthesis, growth)
- **Mech. Eng.** (thermal, packaging)
- **Physics** (modeling)

Questions ??


Collaborative processing among Sensor nodes
Static Sensor node
Useful information
Transient mobile users
Event
User query

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