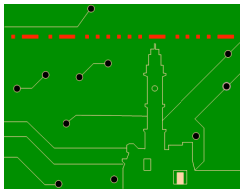




Toward Precision Agriculture: Building a Soil Wetness Multi-Hop WSN from First Principles

Aggelos Bletsas, Aikaterini Vlachaki, **Eleftherios Kampianakis**, George Sklivanitis, John Kimionis, Konstadinos Tountas, Megasthenis Asteris and Panagiotis Markopoulos

Telecom Lab
Department of Electronic and Computer Engineering (ECE)
Technical University of Crete (TUC)

April 5, 2011

Outline

WHY?

Why reinventing the wheel?

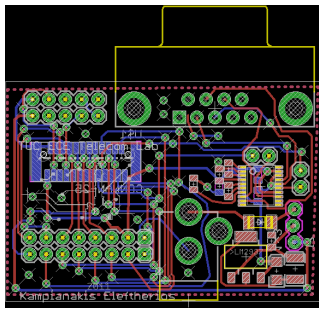
- Cost reduction: from €120 per WSN node $\rightarrow$ €20 per node!
- Research: Low-cost testbed for telecom research (localization, cognition, mobility, etc).
- Research: New sensors, new applications.
- Teaching: Telecom Synthesis course.
- FUN :)

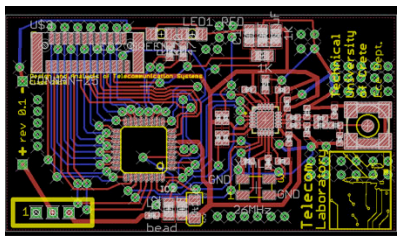
Outline

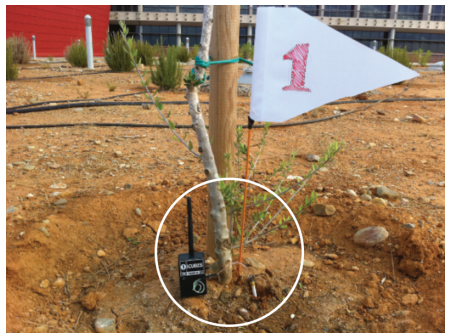
WHAT? (Hardware - (1))

- **iCubes** are WSN nodes.
- SiLabs $\mathrm{C8051F320}$ MCU.
- TI/Chipcon $\mathrm{CC2500}$.
- 2× AA battery operation.
- Custom PCB design.

- Emphasis to simplicity and flexibility.
- Extension Board (XT) for **iCube** (power jack, UART, JTAG and MCU pinouts).
- **iCube** + XT = **iCube** Gateway.

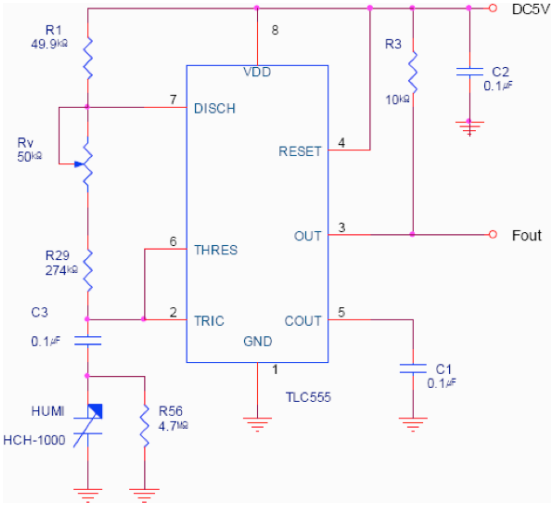


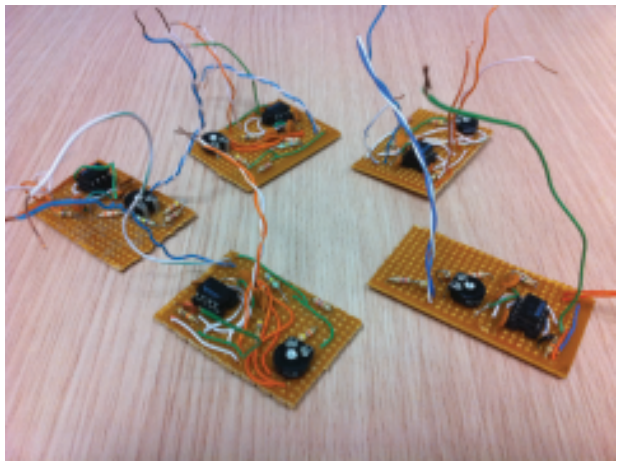


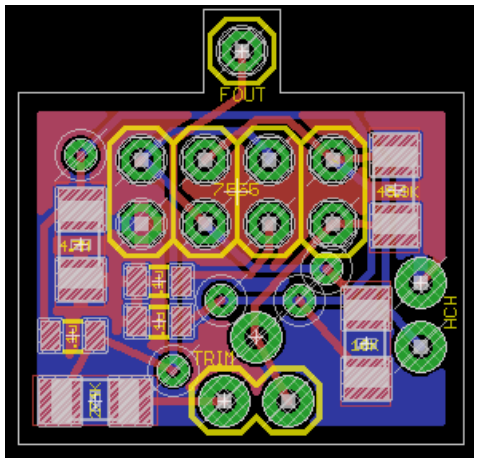


The Humidity Sensor (Hardware - (2))

Ultra low power ($300\mu A$ max), low cost ($\times 5$ cheaper compared to prior art).







Manufacturer	iCubes	Honeywell	Honeywell	Sensirion	Sensirion	Sensirion
Model	Custom-with HCH1000	HIH3610	HIH4000	SHT1x	SHT7x	SHT21
Range ($\%RH$)	0-100	0-100	20-95	0-100	0-100	0-100
Supply Voltage (V)	2-18	4-5.8	4-5.8	5	5	2.1-3.6
Current Consumption (μA)	300	200	500	550	550	270
Accuracy ($\%RH$)	± 3	± 0.2	± 3.5	± 2 - 3	± 1.8 - 3	± 2
Response Time (sec)	15	15	15	4	4	8
Output Type	Voltage Pulses (var. freq.)	Voltage	Voltage	Data (2-wire)	Data (2-wire)	Data (2-wire)
Cost (€)	6	30	24	19 - 22	22 - 25.5	15

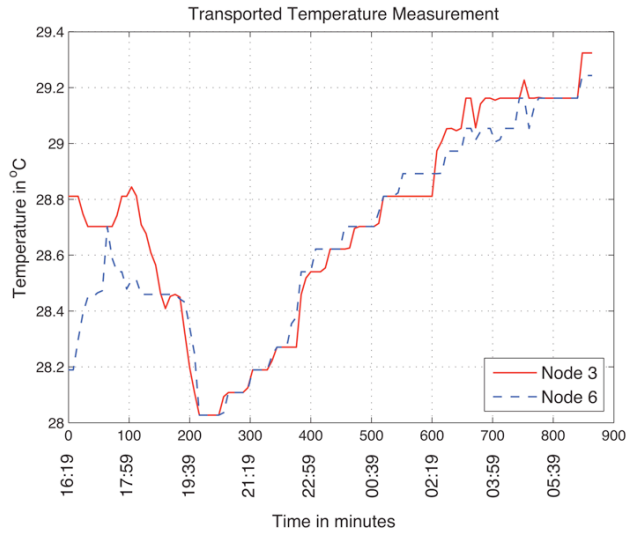
The iCubes Software

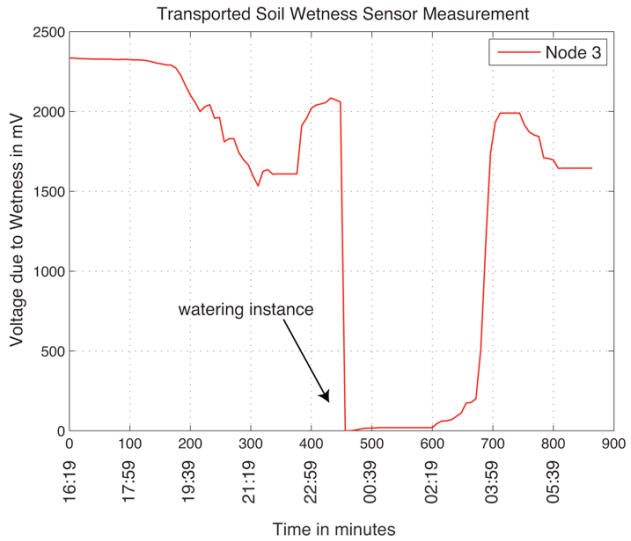
- Flexibility of C routines
  - BOOL send_packet(BYTE destination_id, bit pack_type, bit wait_for_ack, UINT16 timeout, BYTE max_tries, BYTE sn)
  - BOOL receive_packet(BYTE *length, BYTE source_id, bit type, BYTE packet_acceptance_level, UINT16 timeout, BYTE sn)

- **Over the air programming capability (OTAP) has been developed**.

The WSN application towards water management

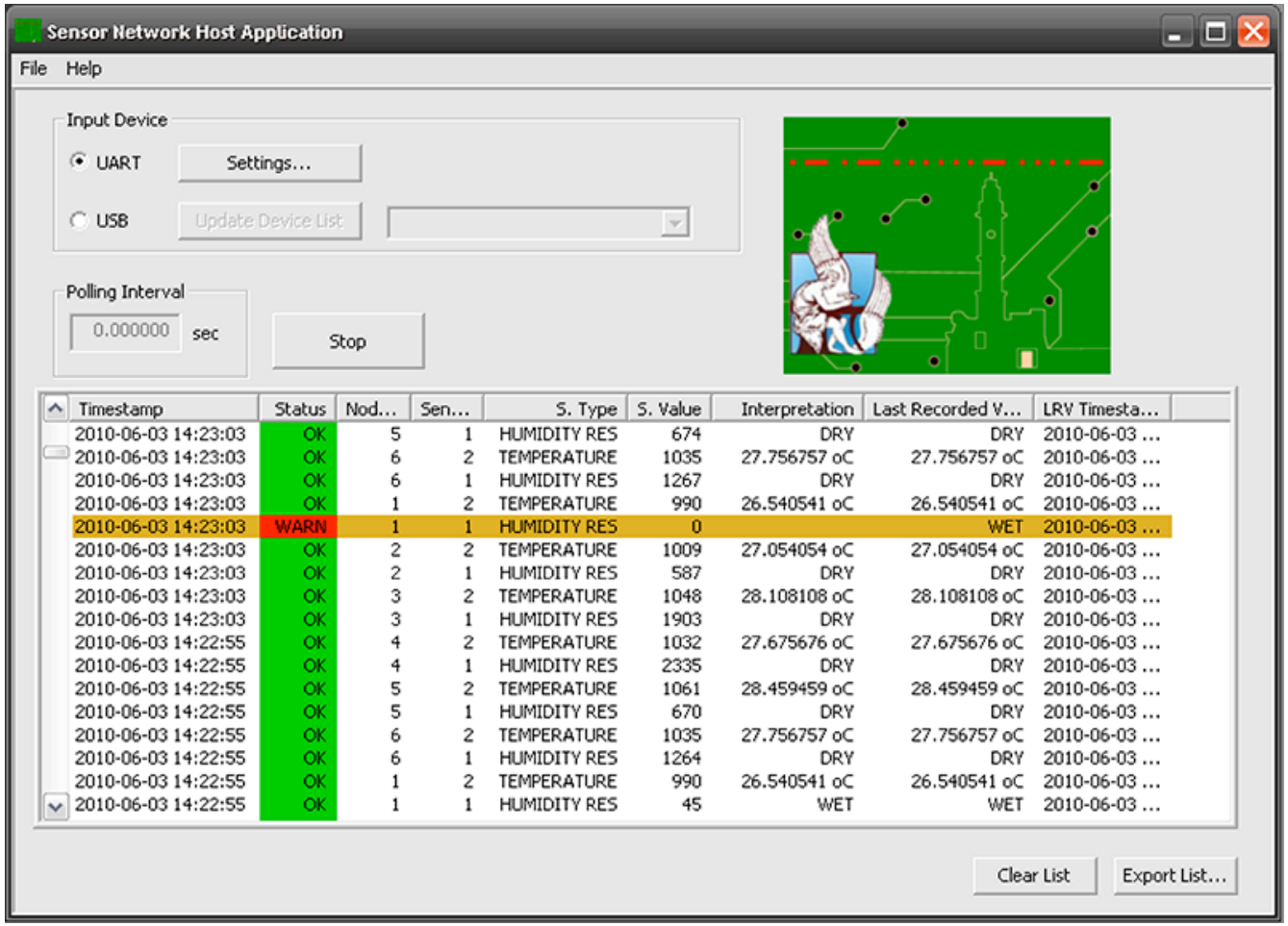
Successful iCubes WSN demo set up taking humidity and temperature measurements (built-in thermistor).





The Gateway Interface - collected information

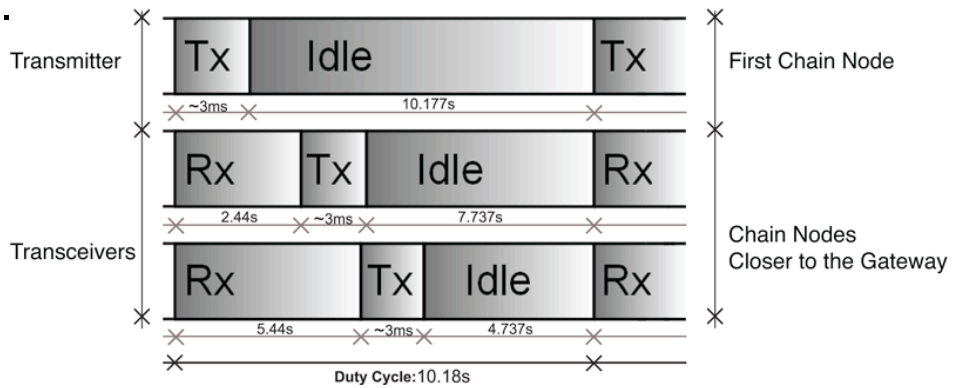
Due to simple gateway - PC interface (single UART buffer), development of another UI is trivial.

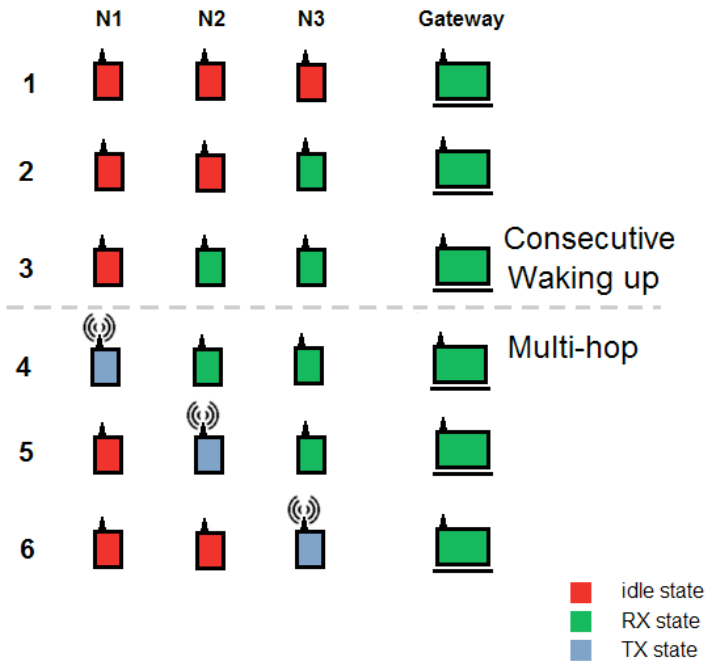


Timestamp	Status	Nod...	Sen...	S. Type	S. Value	Interpretation	Last Recorded V...	LRV Timesta...
2010-06-03 14:23:03	OK	5	1	HUMIDITY RES	674	DRY	DRY	2010-06-03 ...
2010-06-03 14:23:03	OK	6	2	TEMPERATURE	1035	27.756757 oC	27.756757 oC	2010-06-03 ...
2010-06-03 14:23:03	OK	6	1	HUMIDITY RES	1267	DRY	DRY	2010-06-03 ...
2010-06-03 14:23:03	OK	1	2	TEMPERATURE	990	26.540541 oC	26.540541 oC	2010-06-03 ...
2010-06-03 14:23:03	WARN	1	1	HUMIDITY RES	0		WET	2010-06-03 ...
2010-06-03 14:23:03	OK	2	2	TEMPERATURE	1009	27.054054 oC	27.054054 oC	2010-06-03 ...
2010-06-03 14:23:03	OK	2	1	HUMIDITY RES	587	DRY	DRY	2010-06-03 ...
2010-06-03 14:23:03	OK	3	2	TEMPERATURE	1048	28.108108 oC	28.108108 oC	2010-06-03 ...
2010-06-03 14:23:03	OK	3	1	HUMIDITY RES	1903	DRY	DRY	2010-06-03 ...
2010-06-03 14:22:55	OK	4	2	TEMPERATURE	1032	27.675676 oC	27.675676 oC	2010-06-03 ...
2010-06-03 14:22:55	OK	4	1	HUMIDITY RES	2335	DRY	DRY	2010-06-03 ...
2010-06-03 14:22:55	OK	5	2	TEMPERATURE	1061	28.459459 oC	28.459459 oC	2010-06-03 ...
2010-06-03 14:22:55	OK	5	1	HUMIDITY RES	670	DRY	DRY	2010-06-03 ...
2010-06-03 14:22:55	OK	6	2	TEMPERATURE	1035	27.756757 oC	27.756757 oC	2010-06-03 ...
2010-06-03 14:22:55	OK	6	1	HUMIDITY RES	1264	DRY	DRY	2010-06-03 ...
2010-06-03 14:22:55	OK	1	2	TEMPERATURE	990	26.540541 oC	26.540541 oC	2010-06-03 ...
2010-06-03 14:22:55	OK	1	1	HUMIDITY RES	45	WET	WET	2010-06-03 ...

MAC / Routing

- Packet driven multi-hop TDM/FDM routing protocol.
- No need for clock synchronization.
- Packet-driven with highly unsynchronized WSN nodes.
- Tree-based hierarchy.
- Exploiting multiple carriers (one for each subtree).





Outline

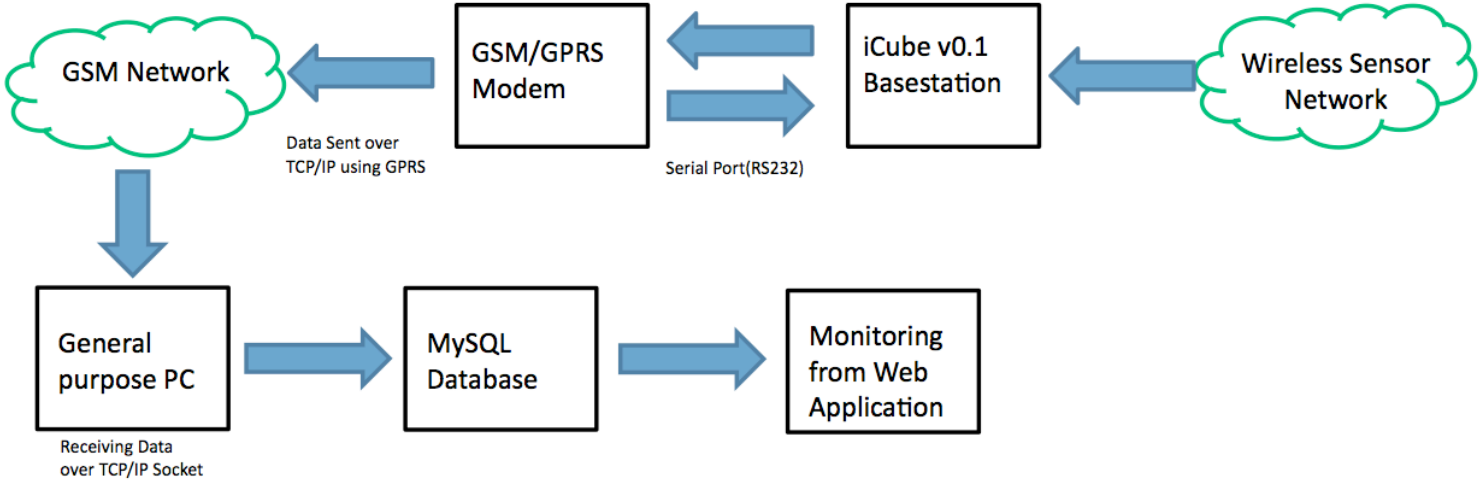
Comparison

- iCubes cost: $\sim$ 30€(quantities of 10)
  Prior art: $\sim$ 120€(of similar functionality).
- Power consumption: comparable to prior art.
- iCube humidity sensor is power/cost competitive to commercial products.
- iCubes development cycle: short
  (simple C based on structured and embedded programming).
- OTAP - capable without the use of RTOS!

Outline

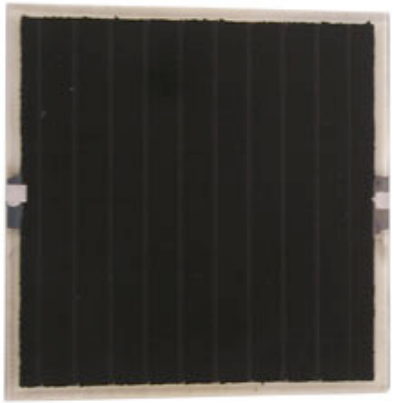
GPRS-enabled WSN gateway

Capability of sending data through GPRS to remote database.



Renewable energy sources

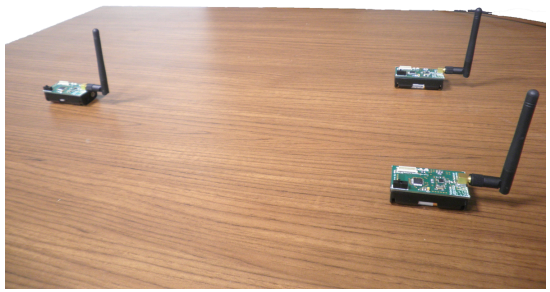
Solar/Wind power utilization.



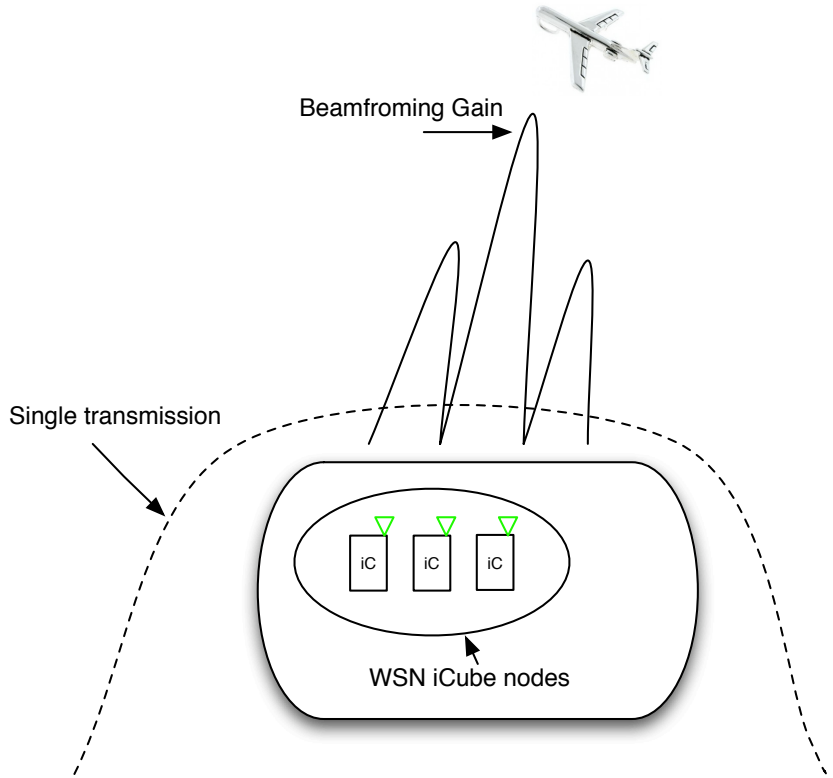
Website: http://www.telecom.tuc.gr/∼aggelos/tel412_fall2010/

Testing Emergency Radio Applications

- Perhaps first of a kind collaborative beamforming demonstration.
- Zero-feedback, zero CSI distributed beamforming.
- Ideal for reachback communication in low-cost WSNs.



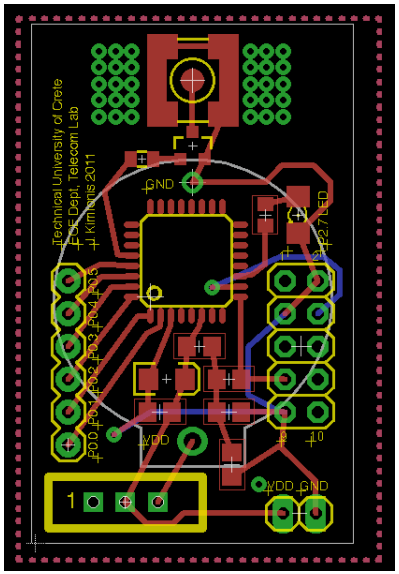
- Low-cost testbed (iCubes and USRP BS).

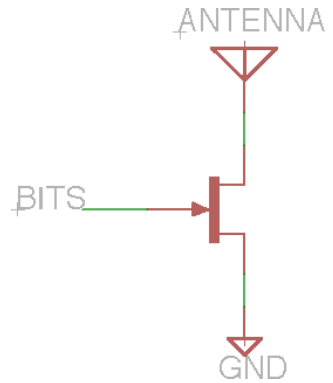


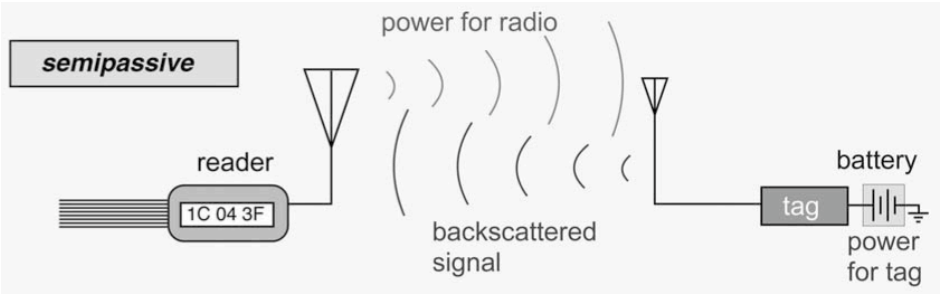
A. Bletsas, A. Lippman and J.N. Sahalos, "Simple, Zero-Feedback, Distributed Beamforming with Unsynchronized Carriers", **IEEE Journal on Selected Areas of Communications (JSAC)**, Special Issue on Simple Sensor Networking Solutions, Vol. 28, No. 7, pp.1046-1054, Sept. **2010**.

Backscatter Sensor Networks

- **Single transistor** WSN radio.
- Ultra low cost.
- Ultra low power.
- Ideal for environmental WSNs.
- Challenge: increase range.



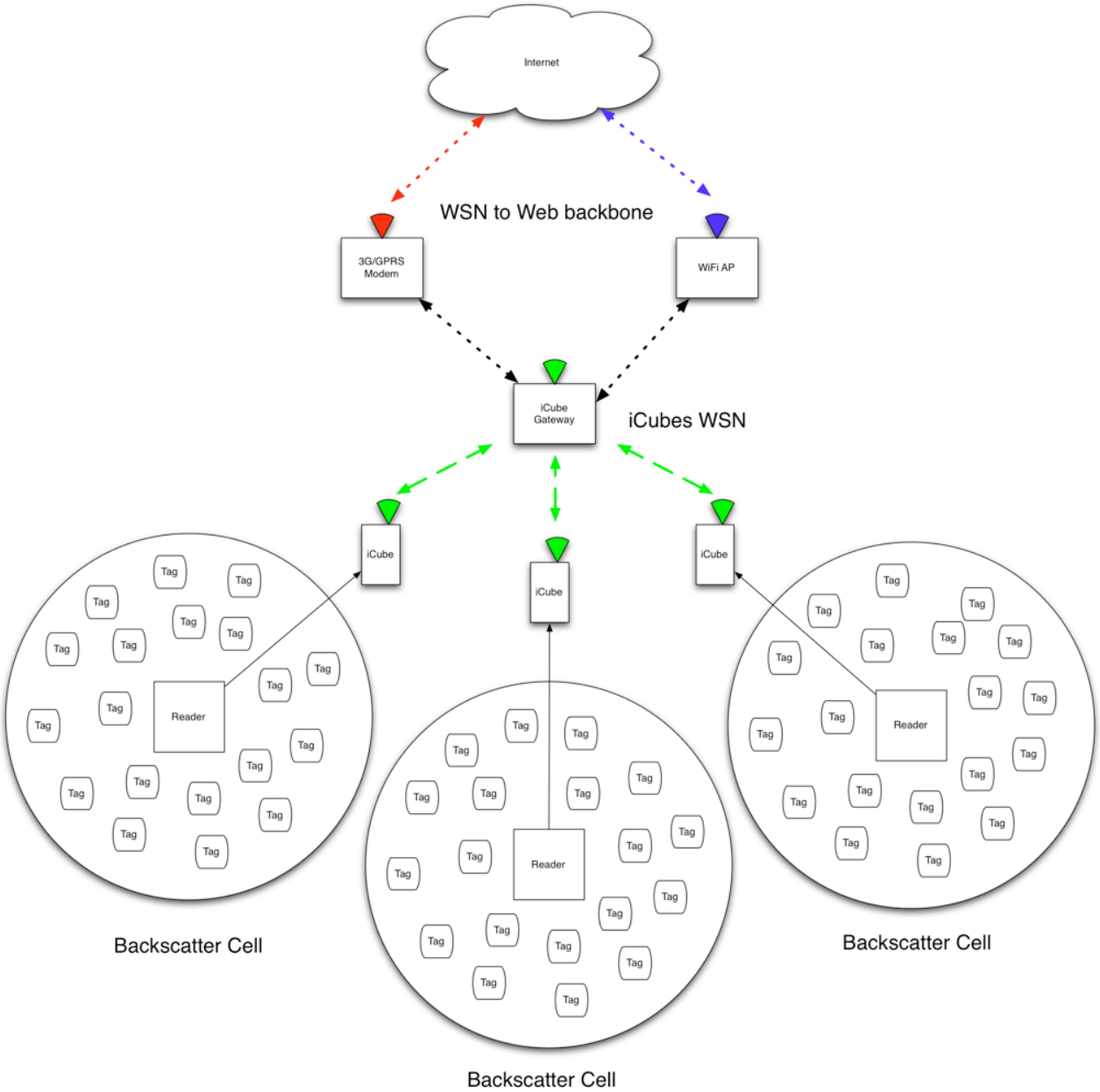




A. Bletsas, A.G. Dimitriou and J.N. Sahalos, "Improving Backscatter Radio Tag Efficiency", **IEEE Transactions on Microwave Theory and Techniques (MTT)**, Vol. 58, No.6, pp. 1502-1509, June **2010**.

G. Vannucci, A. Bletsas and D. Leigh, "A Software-Defined Radio System for Backscatter Sensor Networks", **IEEE Transactions on Wireless Communications (TWC)**, Vol. 7, No. 6, pp. 2170-2179, June **2008**.

The BIG picture



Conclusion

- WSNs can be low cost, easy, modular and fun!
- New disruptive technologies are being developed @ TUC/Telecom Lab.

Thank YOU! Questions?

Eleftherios Kampianakis (kampianakis@gmail.com)

Contact info: Aggelos Bletsas

Assistant Professor
Telecom Lab
Electronic & Computer Engineering Dept.
Technical University of Crete, Greece

aggelos@telecom.tuc.gr
aggelos@media.mit.edu

website: http://www.telecom.tuc.gr/∼ aggelos