Ming Hsieh Department of Electrical Engineering

Soil Subsurface Wireless Communication System

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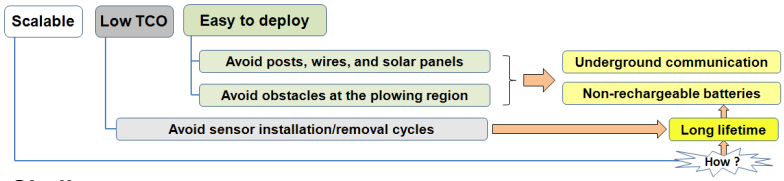
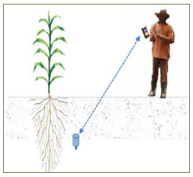
Main Goal & Research Challenges

- **Goals and Research Strategy:**

Design and real-world implementation of a subsurface wireless communication system which: a) has low TCO (total cost of ownership) and b) is easy to deploy and operate



Irrigation control

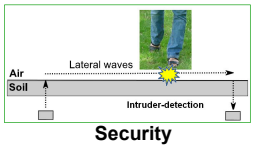


Subsistence farming

- **Main Challenges:**

1) *Achieve multi-year lifetime for non-rechargeable batteries* [1]
2) *Achieve communication range +15 meters under low-power regime*
3) *An environment agnostic solution: soil conditions cannot impact performance*

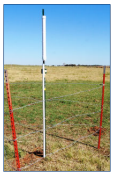
Current Readiness:

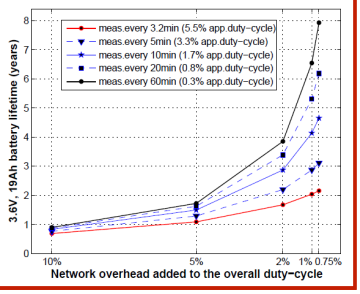


Security

BETS: a novel cross-layer protocol for low duty-cycle WSNs [2]

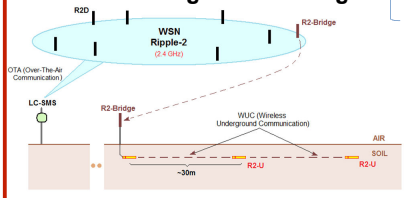
- **Our existing over-the-air solution:**
  - Current application: SoilSCAPE project for the NASA's SMAP Mission
  - Time-proven solution (~2 years)
  - Network overhead <0.5%
  - Currently, the most energy-efficient known solution for wireless sensor networks (WSNs)
- **Results (consider a 0.3% application duty-cycle)** [2,3] **:**
  - Typical WSNs: network overhead ~5%
  - BETS solution: node lifetime extended by ~350%
- **BETS-UG: on-going research toward soil subsurface communication:**
  - Support store-and-forward mechanism (agriculture)
  - Support for event-driven applications (security and emergency response) [3]

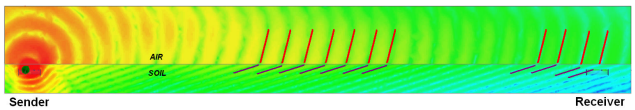




LWWSN Antenna: Lateral-Wave Based Antenna

- **Related work:**
  - ☹ Communication range <1m (433MHz, 10mW tx power, 17cm quarter-wave monopole antenna) [4]
  - ☹ Communication range ~20m (27MHz, +1W tx power, 2.8m quarter-wave monopole antenna) [5]
  - 😐 Magnetic-Induction method: under development (so far, low power devices are not available)
- **Our work:**
  - Based on previous investigation of insulated antennas for submarine comm. (1950-80's) [4]
  - Novel design considering:
    - antenna cost (<$10), ease of installation, and dimensions (<60cm)
    - multi-point communication, and environment-transparency





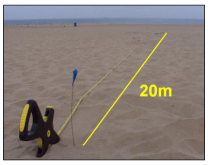
Sender Receiver

- **Preliminary results with the new antenna:**
  Setup: 30cm depth, 433MHz, 10mW

☺ El Segundo Beach, CA (29Jul13):
- Comm. range 20m (90% PRR*)
- Comm. range 15m (100% PRR)

☺ Bureau Land Mng., Jackson, CA (20Aug13):
- Comm. range 20m (57% PRR)
- Comm. range 18m (100% PRR)

* PRR: Packet Reception Rate



Conclusions & Future Work

- Soil subsurface communication based under low-power regime is feasible (~20 folds for communication range).
- A detailed study of different types of insulated antennas for subsurface communication is still needed for comparison.
- We plan to conclude the design of the BETS-UG and the LWWSN antenna by the first semester of 2014.

References

[1] Agnelo Silva, Mingyan Liu, and M. Moghaddam . "Power Management Techniques for Wireless Sensor Networks and Similar Low-Power Devices Based on Non-Rechargeable Batteries," *EURASIP Journal on Wireless Communications and Networking*, vol. 2012, Article 757291, August 2012.
[2] Agnelo Silva, Mingyan Liu, and M. Moghaddam . "BETS: Best-Effort Time-Slot Allocation Networking Protocol for 2-Tier Wireless Sensor Networks," *Proc. ACM MiSeNet'12*, August 2012.
[3] Agnelo Silva, Mingyan Liu, and M. Moghaddam. "An Adaptive Energy-Management Framework for Sensor Nodes with Constrained Energy Scavenging Profiles," *Hindawi Journal of Distributed Sensor Networks*, vol. 2013, Article 272849, August 2013.
[4] Agnelo Silva, "Channel characterization for wireless underground sensor networks," Master of Science Thesis, Univ. of Nebraska at Lincoln, April 2010 (http://digitalcommons.unl.edu/computerscidiss/13)
[5] J. Huang et al, "Development of a Wireless Soil Sensor Network," Proc. ASABE Annual International Meeting, Providence, Rhode Island, 2008.

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