Center for Embedded Systems

An NSF Industry/University Cooperative Research Center

Reliable Wireless Communications in Aircraft and Other Challenging Environments

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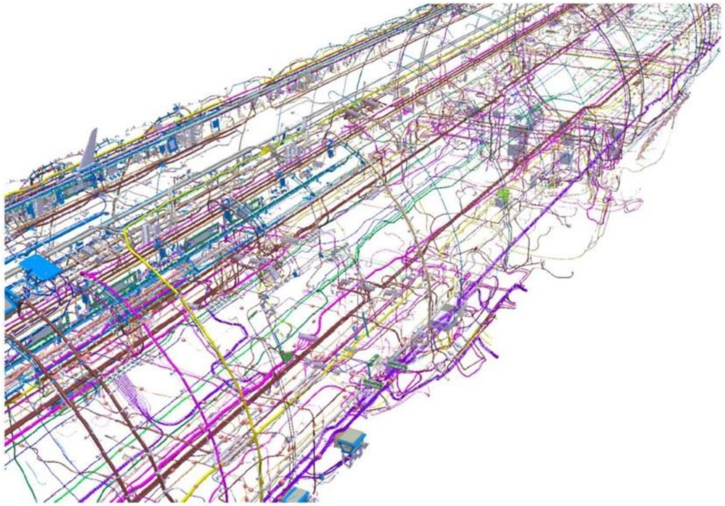
Project Overview and Description

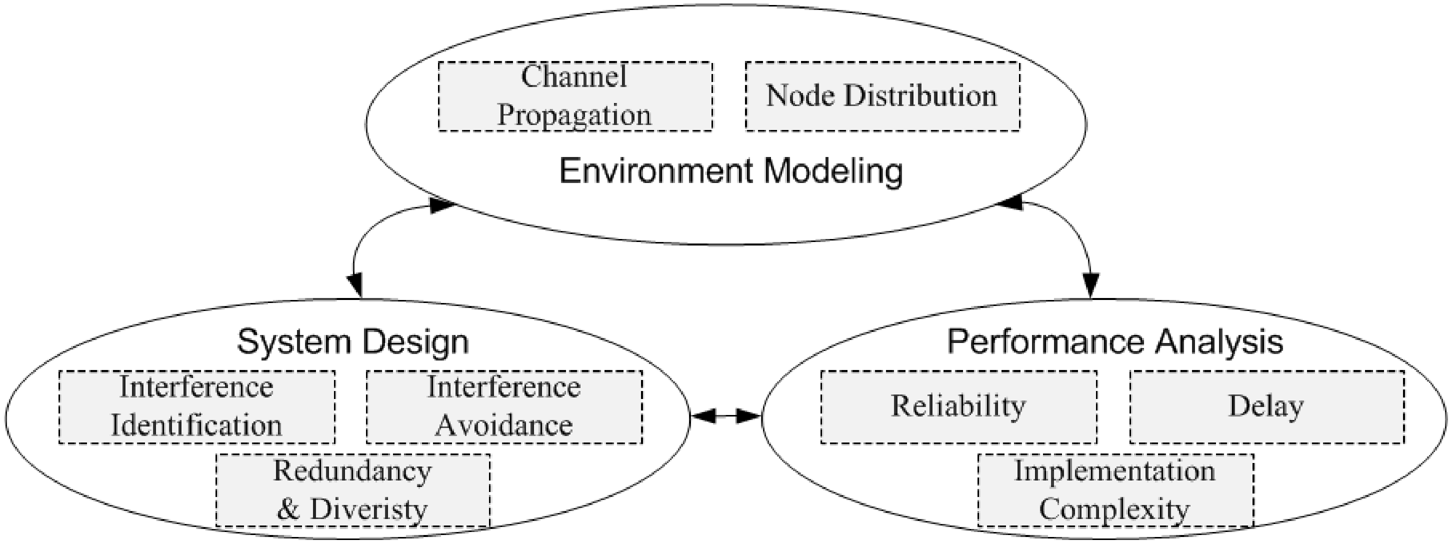
Potential Industry Sponsor – UTC Aerospace Systems

- **Problem**
  - Conventional wired connections
    - issues in weight, cost, safety, maintainability
  - Current wireless connections
    - not reliable enough
- **Potential applications**
  - Aircraft
    - safety-critical
    - diagnostic
  - Hazard detection
    - fire, gas leaks
    - structural weakness



Electrical systems in A350.

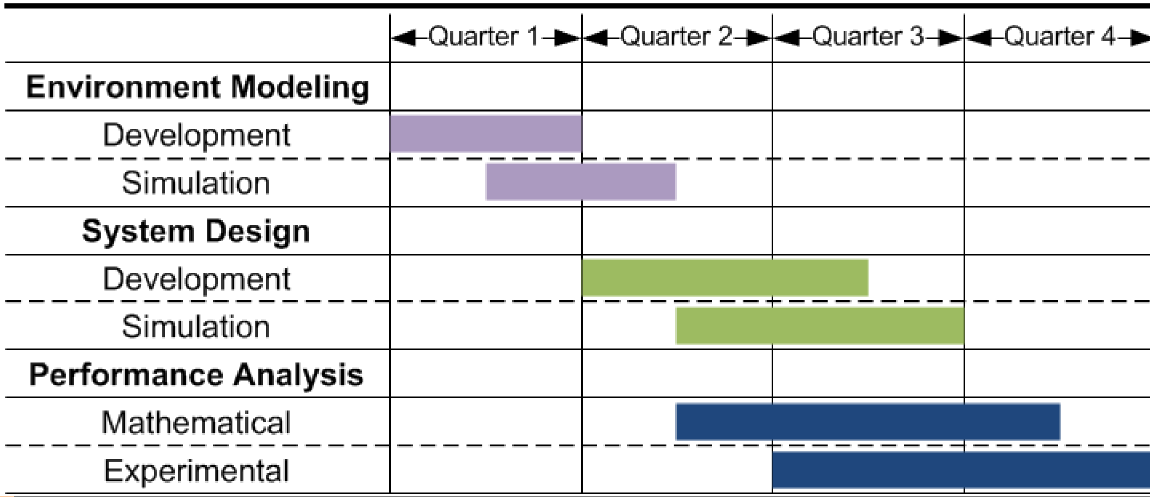
Approach



- **Novelty**
  - Tailored to specific operational environments
  - Robustness against interference and failure
  - Flexible balance between reliability and cost
- **Potential benefits**
  - Development and integration of reliable wireless systems
  - Feasibility validation of wireless solutions and products

Project Tasks/ Deliverables

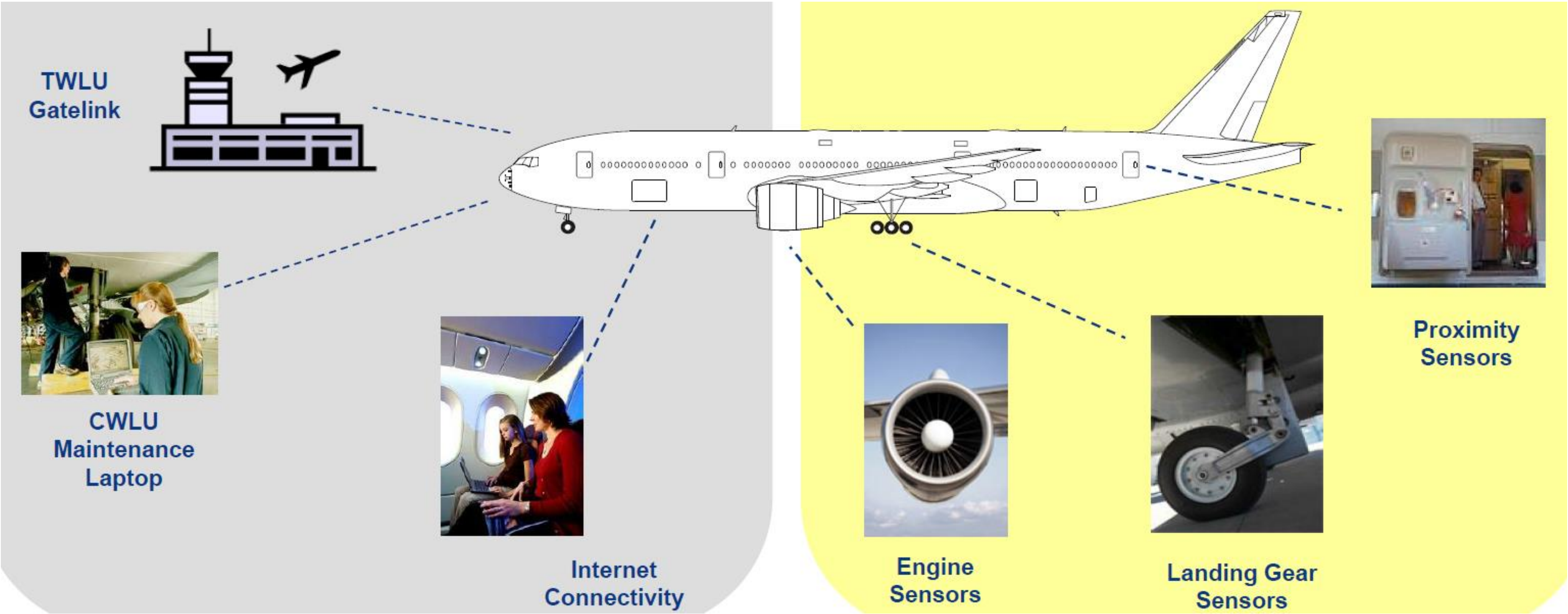
	Description	Date	Status
1	Environment modeling - development	08/15/2013-11/14/2013	
2	Environment modeling - simulation	10/01/2013-12/31/2013	
3	System design - development	11/15/2013-03/31/2014	
4	System design - simulation	01/01/2014-05/14/2014	
5	Performance analysis - mathematical	01/01/2014-06/30/2014	
6	Performance analysis - experimental	02/15/2014-08/31/2014	



midterm report & presentation
conference/journal paper 1

conference/journal paper 2
simulation programs
final report & presentation

Intra-Aircraft Wireless Applications



M. Ost and C. Pichavant, "Update on wireless avionics intra-communications: ITU-R update and future regulatory considerations," ICAO WG-F Meeting, Dakar, Senegal, Oct. 2011.

J. Cramer, "Update on WRC-12 Issues Impacting Wireless Avionics Intra-Communications," ITU-R Working Party 5B and Future Regulatory Considerations, Sept. 2010.

Application Classification

Low data rate, interior

- *Sensors:* cabin pressure - smoke detection - fuel tank/line - proximity - temperature - EMI incident detection - structural health monitoring - humidity/corrosion detection
- *Controls:* emergency lighting - cabin functions

Low data rate, outside

- *Sensors:* ice detection - landing gear position feedback - brake temperature - tire pressure - wheel speed - steering feedback - flight controls position feedback - door proximity - engine sensors - cargo compartment - structural sensors

High data rate, interior

- *Sensors:* air data - engine prognostic - flight deck/cabin crew still imagery / video
- *Comm.:* avionics communications bus - FADEC aircraft interface - flight deck/cabin crew audio / video (safety-related) - flight operations related digital data (e.g. EFOS)

High data rate, outside

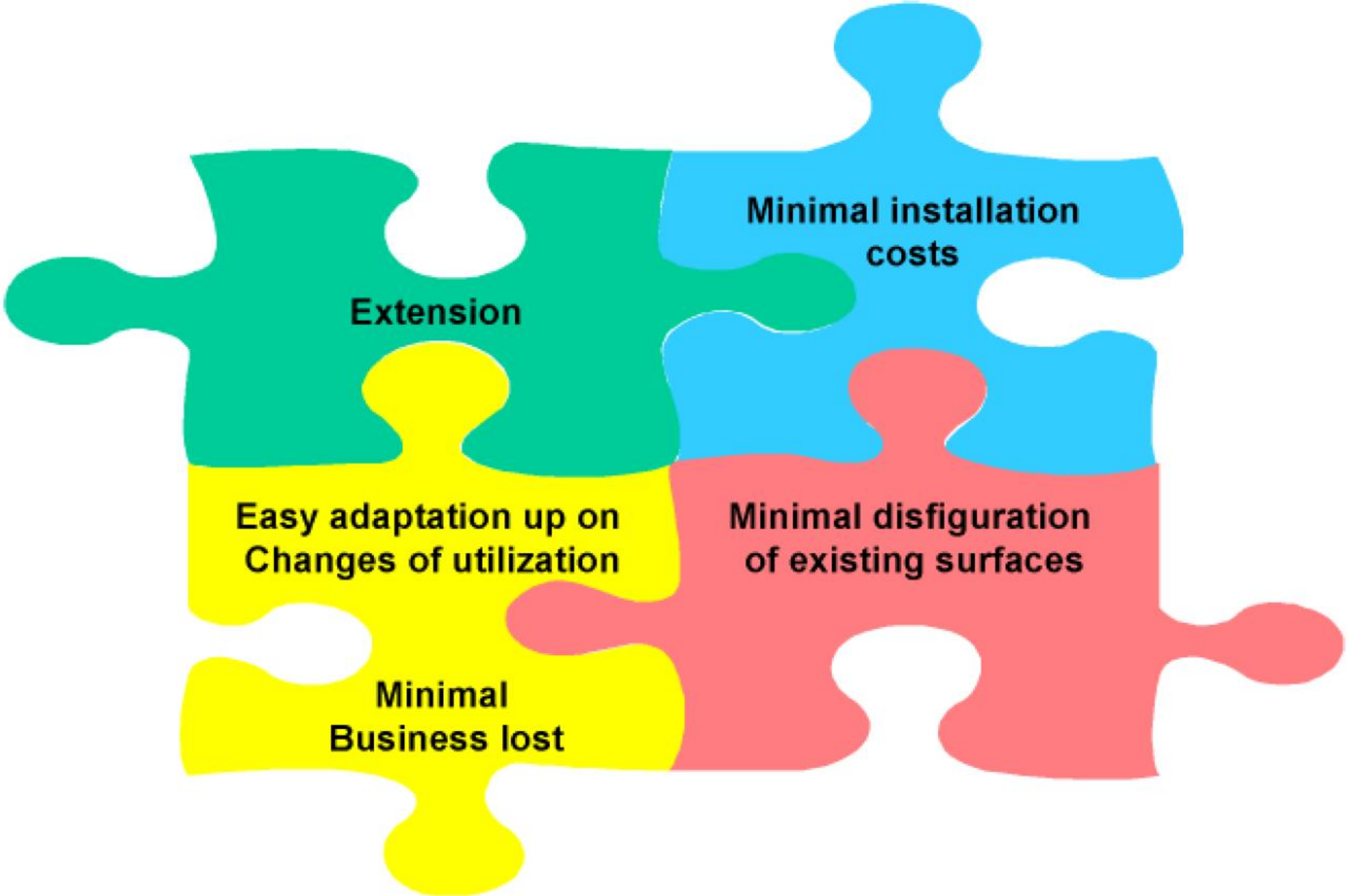
- *Sensors:* structural health monitoring - imaging sensors (still and video)
- *Controls:* active vibration control
- *Comm.:* avionics communications bus

Application Characteristics

	LI	LO	HI	HO
Installation	Inside	Outside	Inside	Outside
Propagation	NLOS	LOS	LOS/NLOS[1]	LOS/NLOS
Refresh rate	Multiperiodic	Multiperiodic	Multiperiodic+burst	Multiperiodic
Data-rate	< 10 kbps	< 10 kbps	>10 kbps	>10 kbps
Transmission range	50 cm - 15 m	5-50 m	50 cm - 15 m	5-50 m
Time criticality	Soft	Soft/Hard	Soft/Hard	Soft/Hard
Latency	1 s	0-2.5 ms	< 500 ms	1 ms
Jitter	-	-	< 50 ms	-
Operation time	AFP+GO+T/CFP[2]	AFP+GO+T/ CFP	AFP+GO+T	AFP+GO+T
Nr. Of nodes	3,500	900	100	300

O. Elgezabal and C. Salazar, “Technological foundation for future intra-aircraft wireless applications: Technology assessment,” *4th Annual Caneus Fly by Wireless Workshop (FBW)*, June 2011.

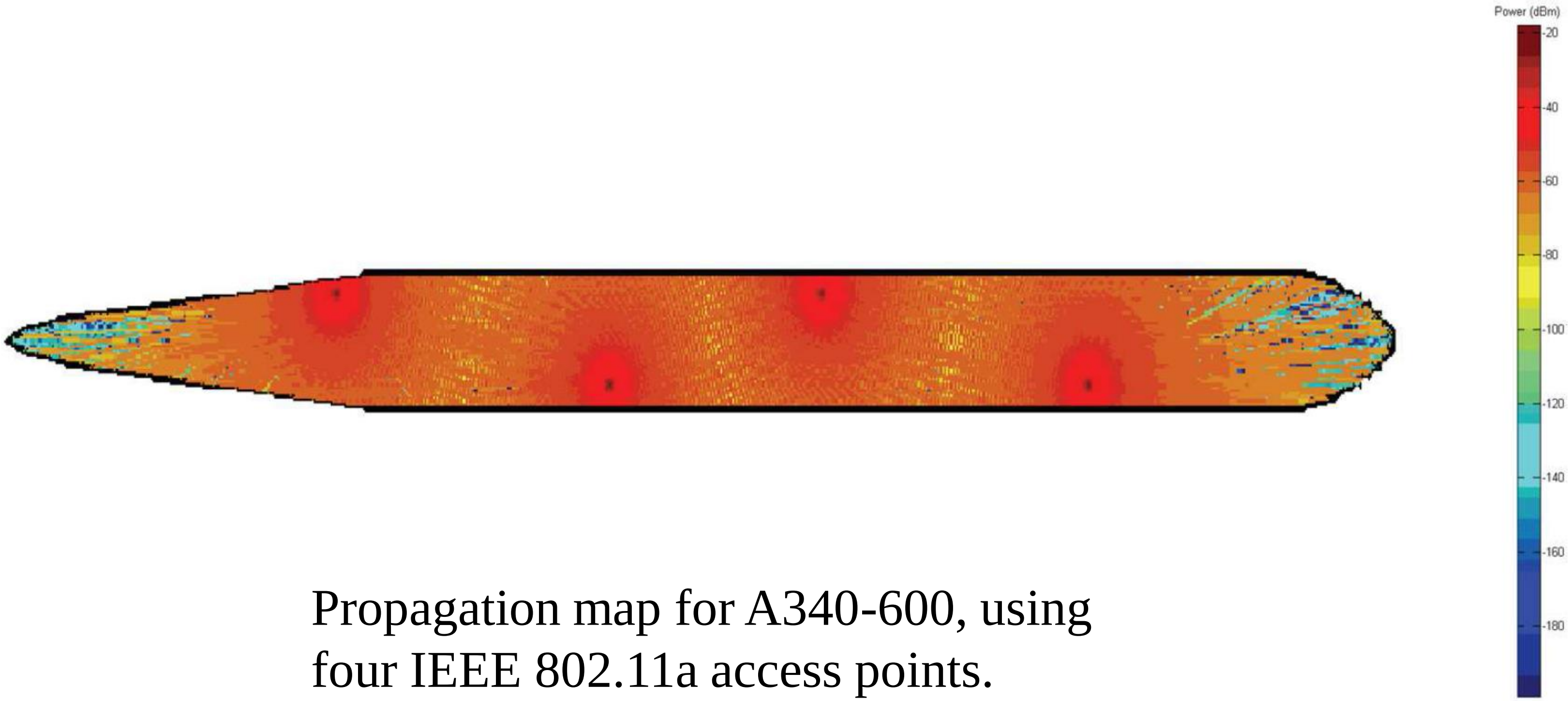
Market Requirements



F. Derbel, "Reliable wireless communication for fire detection systems in commercial and residential areas," in *Proc. IEEE Wireless Commun. and Networking Conf. (WCNC)*, Mar. 2003.

Environment Modeling

- Geometry inside an aircraft contains high density clutter.
- Ray tracing techniques introduce an acceptable representation.



Propagation map for A340-600, using four IEEE 802.11a access points.

C. J. Debono, R. A. Farrugia, and K. Chetcuti, “Modelling of the wireless propagation characteristics inside aircraft,” in *Aerospace Technologies Advancements*, T. T. Arif, Eds. InTech, 2010.

Interference Identification

- **Clear channel assessment**
  "listen before talk"
  - Energy-based
  - Correlation-based
  - Mixed
- **Considerations**
  - Reliability
  - Delay constraint
  - Cost

D. Cabric, S. M. Mishra, and R. W. Brodersen, "Implementation issues in spectrum sensing for cognitive radios," in *Proc. IEEE Asilomar Conf. Signals, Syst. and Comput.*, Pacific Grove, CA, Nov. 2004, pp. 772–776.

Interference Identification (cont.)

- **Periodic channel sensing**

…	Sensing	Transmission	Sensing	Transmission	…

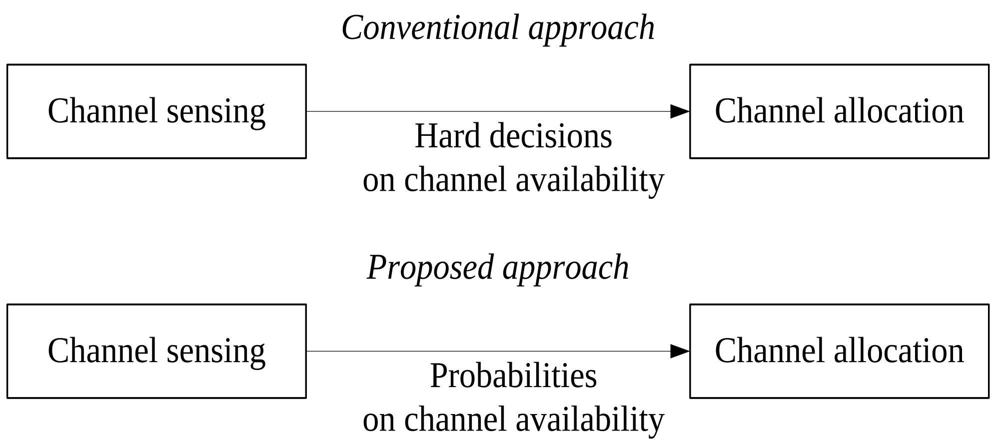
- **Sequential detection**
  - Quickest identification of interference
  - NOT to wait for a fixed number of samples
  - Providing assessment as early as possible

X. Zhou, G. Y. Li, Y. H. Kwon, and A. C. K. Soong, “Detection timing and channel selection for periodic spectrum sensing in cognitive radio,” in *Proc. IEEE Global Commun. Conf. (GLOBECOM)*, Nov. 2008.

L. Lu, X. Zhou, and G. Y. Li, “Optimal sequential detection in cognitive radio networks,” in *Proc. IEEE Wireless Commun. and Networking Conf. (WCNC)*, Apr. 2012.

Interference Avoidance

- **Probabilistic channel allocation**
  "soft", rather than "hard"

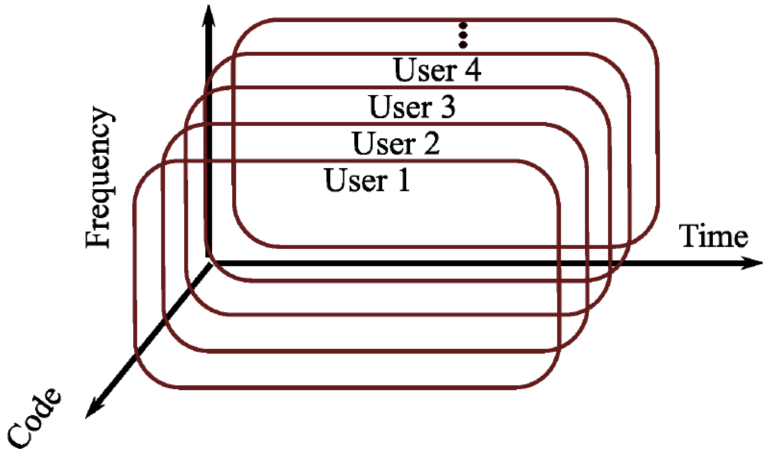


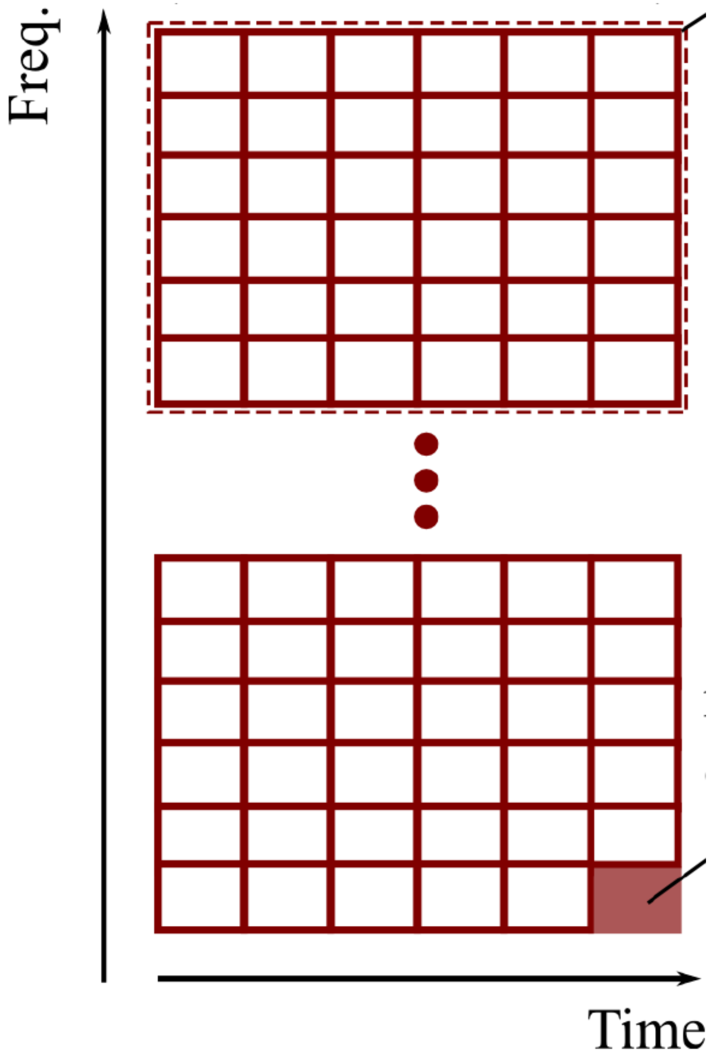
- **Joint channel sensing and allocation**
  - Transmission success/failure after channel allocation can also assist channel sensing

X. Zhou, G. Y. Li, D. Li, D. Wang, and A. C. K. Soong, "Probabilistic resource allocation for opportunistic spectrum access," *IEEE Trans. Wireless Commun.*, vol. 9, pp. 2870-2879, Sept. 2010.

Redundancy & Diversity

- **Why?**
  - Node failure
  - Channel fading
- **Spread spectrum with error correction coding**

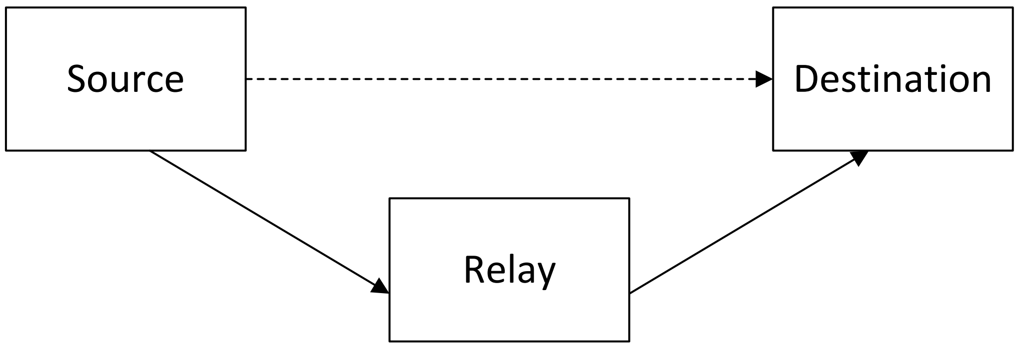




- **Time-frequency interleaving**

Redundancy & Diversity (Cont.)

- **Relaying**



  - Multi-hops
  - Reliable coverage
  - Issues
    - delay
    - end-to-end performance

L. Li, X. Zhou, H. Xu, G. Y. Li, D. Wang, and A. C. K. Soong, "Simplified relay selection and power allocation in cooperative cognitive radio systems," *IEEE Trans. Wireless Commun.*, vol. 10, pp. 33-36, Jan. 2011.

Performance Analysis & Evaluation

- **Focus**
  - Feasibility of individual techniques
  - Overall system performance
- **Guidelines**
  - Throughput, quality-of-service
  - Reliability: bit error, packet loss, outage
  - Delay: point-to-point, end-to-end
  - Implementation complexity

X. Zhou, H. A. Hraishawi, and Y. Jia, "Analysis and design of spectrum sharing in cognitive femtocell networks," submitted to *IEEE Global Commun. Conf. (GLOBECOM)*, 2013.

IP to Generate

- **Report**
  - Midterm report & presentation
  - Final report & presentation
- **Scholarly papers**
  - At least 2 papers at international conferences and/or top journals
- **Invention disclosures if interested**
- **Tools**
  - Simulation programs

Thank you!

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