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Coordinated Jamming and Communications (CJamCom)

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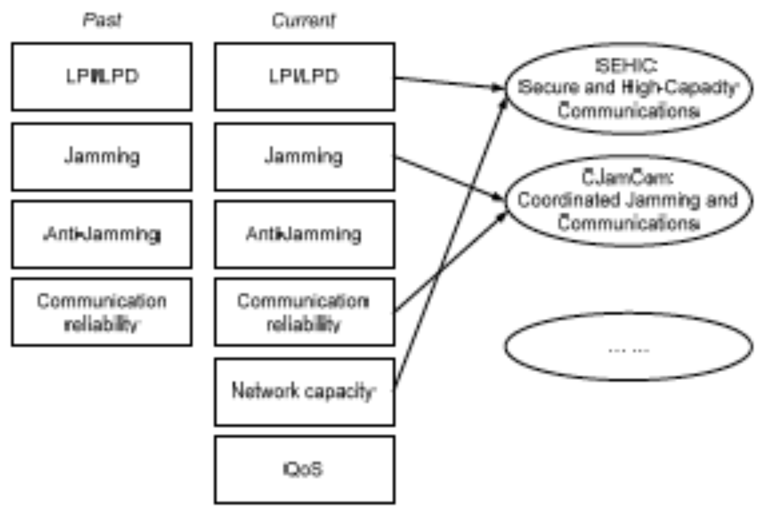
Outline

1. Introduction
2. Requirements in jamming & communications systems
3. Fundamental technologies
4. Coordinated jamming and communications
5. SDR/CR and CJamCom implementation
6. Recent cognitive radio research results

1. Introduction

- Research in military communications: Past and present
- Advances in information networking, signal processing, radio and antenna technologies
- Key idea for CJamCom

Research in Military Communications: Past and Present



- Identification and investigation of new R&D topics in military communications

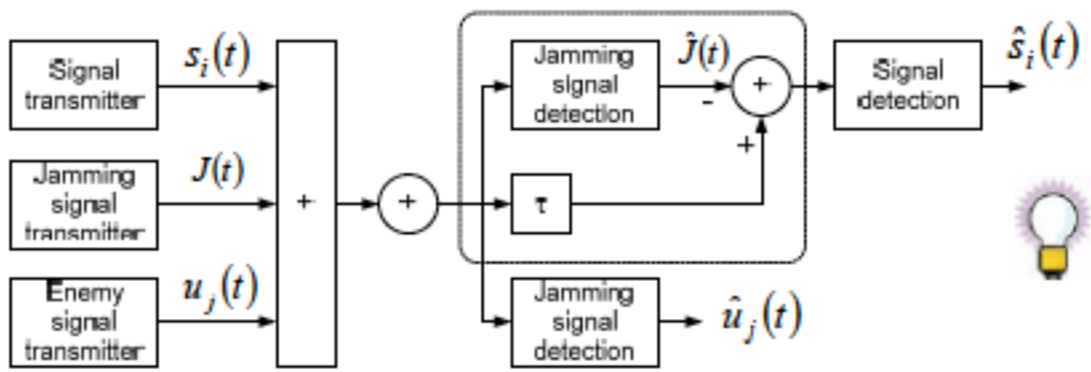
Research in Military Communications: Past and Present

- Why we have new R&D topics
  - New battlefield scenarios (IED/improvised explosive device, cyber attacks, etc.)
  - New services/applications (Internet, multimedia, etc.)
  - New communications requirements (high throughput/data rate, delay constrains, etc.)
  - New theory, technologies (high-speed DSP, SDR, etc.)

Technological Advances for Milcom

- Information networking: Internet, multimedia networking
- Localization techniques
- Signal processing algorithms and processors
- SDR and CR concept and theory
- SDR platform
- Antenna technologies: From diversity, to beamforming and MIMO

Key Idea for CJamCom



Key Idea for CJamCom

- The key idea for CJamCom is based on
  - CDMA multi-user detection (MUD) technique
  - Interference cancellation technique

2. Requirements in Jamming and Communications Systems [1]

- LPI/LPD: Low probability of intercept/low probability of detection
  - Intended receiver: cooperative transmission and reception (detection) with know features: carrier frequency, spreading code, or modulation scheme
  - Unintended receiver:
    - LPI: low probability of intercept – detect the presence of radio signals (focus on presence);
    - LPD: low probability of detection
  - Detection Process
    - False Alarm Probability
    - Detection Probability
  - Quality factor
    - Ratio of the intercept range to the range in which the communicators can communicate.
    - Considering other parameters: propagation conditions, antenna gains, modulation types, special signal processors, etc.

Requirements in Jamming and Communications Systems [1, 2]

- Types of detectors
  - Energy detector
  - Optimum intercept receivers
    - Synchronous Coherent Interceptors
    - Synchronous Noncoherent Interceptors
    - Asynchronous Coherent Interceptors
    - Asynchronous Noncoherent Interceptors

Requirements in Jamming and Communications Systems [1]

- Smart jammer
  - For the jammer to be most effective, the jamming signal must be tailored to the SS system and to the actual received power
  - A jammer that has knowledge of the type of signaling being used, can accurately predict the received signal power, and adapt to transmit the optimum jamming signal is called a smart jammer
  - The field of study that includes the design and analysis of jammers and jamming strategies is called electronic counter measures (ECM)
  - SS communications systems are sometimes called electronic counter counter measures (ECCM)

Requirements in Jamming and Communications Systems [3, 4]

- Sign-to-interference-plus-noise ratio
  - SINR = S/(I+N)
- Outage probability
  - Pout = 1 – Prob { SINR > Threshold}
  - Probability distributions of S, I, N
- Bit error rate
  - S, I probability distributions (Channel conditions)
  - Modulation schemes
- Throughput and utilization
  - Data rate; Efficiency
- Network capacity
  - Number of users
- QoS
  - Delay, jitter, image quality/data rate

3. Fundamental Technologies

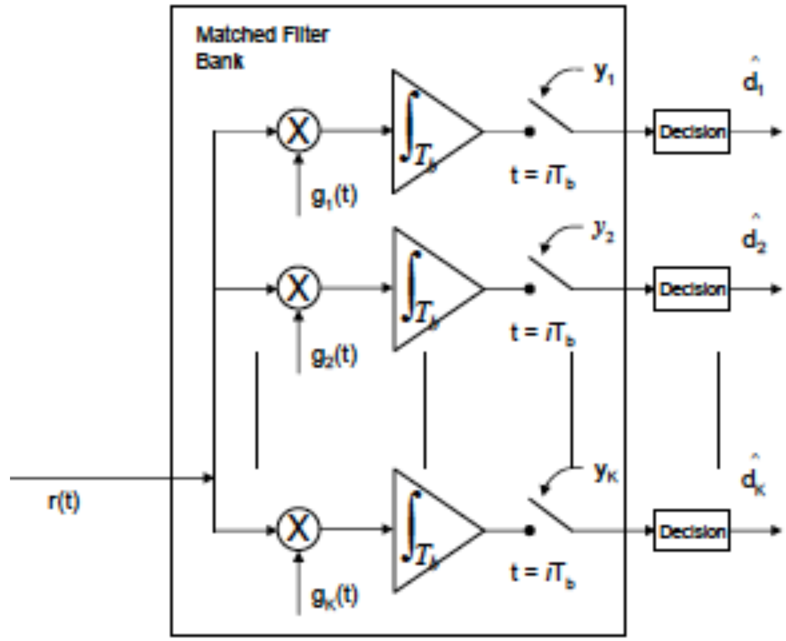
- Spread spectrum
- Multi-user detection
- UWB antenna and communications
- High-speed DSP algorithms and FPGA platform
- Software defined radio (SDR) and cognitive radio (CR)

Spread Spectrum [1, 5]

- DS, FH, DS/FH
- PN codes
- Synchronization and tracking
- LPI/LPD methods and performance
- CDMA
- Rake receiver, MUD, MC-CDMA (OFDM-CDMA), MIMO-CDMA (signal processing techniques)

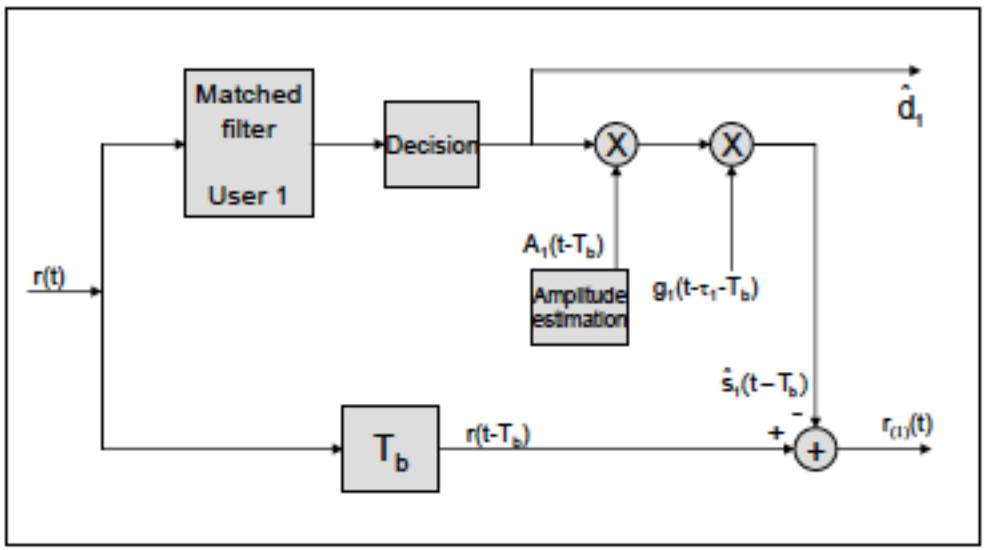
Multi-User Detection

- Conventional detection



Multi-User Detection [6]

- Multiuser detection
- Subtractive interference cancellation



UWB (Ultra-Wideband) [7]

- UWB communications
  - $C = B \log_2 (1 + S/N)$
  - Low power spectrum density
  - Short range
  - FCC, 2/2002; 3.1-10.6 GHz
  - Sensor data, precision localization, etc.
- UWB antennas

DSP Algorithms and FPGA Platform

- DSP algorithms
  - New algorithms for wireless system performance improvement (MIMO, OFDM, MUD, etc.)
  - Efficient algorithms (high speed)
- FPGA platform
  - Field-programmable gate array
  - Reconfigurable
  - High speed
  - Power consumption

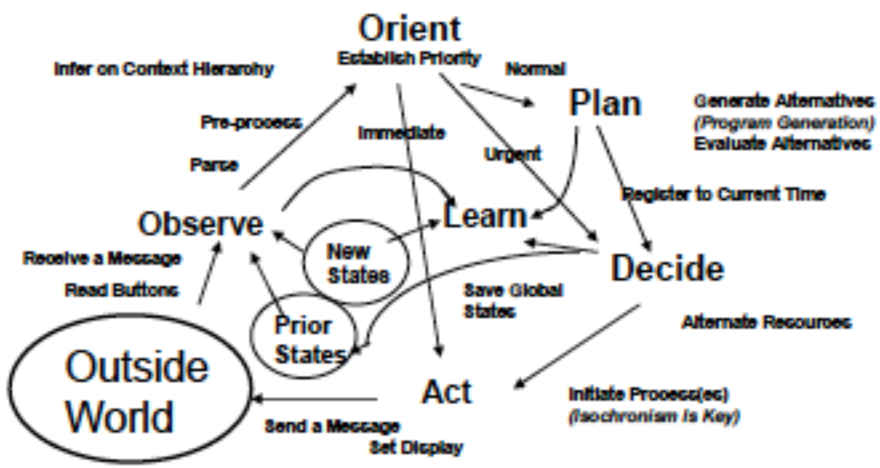
Software Defined Radio (SDR) [8, 9]

- SDR: All functions, modes and applications can be configured and reconfigured by software (frequency range, modulation type, maximum output power, …)
- SDR features
  - Reconfigurability: SDR technology facilitates implementation of future-proof, multi-service, multi-mode, multi-band, multi-standard terminals and infrastructure equipment.
  - Ubiquitous Connectivity: SDR enables implementation of air interface standards as software modules and multiple instances of such modules that implement different standards can co-exist in infrastructure equipment and handsets
  - Interoperability: SDR facilitates implementation of open architecture radio systems; End-users can seamlessly use innovative third-party applications on their handsets as in a PC system

Cognitive Radio (CR) [10, 11]

- Several definitions of Cognitive Radio exist:
  - Mitola: Cognitive radio signifies a radio that employs model based reasoning to achieve a specified level of competence in radio related domains.
  - FCC: A cognitive radio (CR) is a radio that can change its transmitter parameters based on interaction with the environment in which it operates.
  - From ITU Wp8A: A radio or system that senses, and is aware of, its operational environment and can dynamically and autonomously adjust its radio operating parameters accordingly

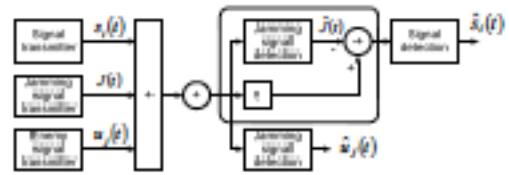
Cognitive Radio (CR) [10, 11]



The Cognition Cycle

4. Coordinated Jamming and Communications

- Concept, theory and techniques
- Modeling, analysis, and simulation



$$r(t)=s_1(t)+\sum_{i=2}^{n}s_i(t)+\sum_{i=1}^{p}u_j(t)+\sum_{i=1}^{q}v_k(t)+J(t)+n(t)$$

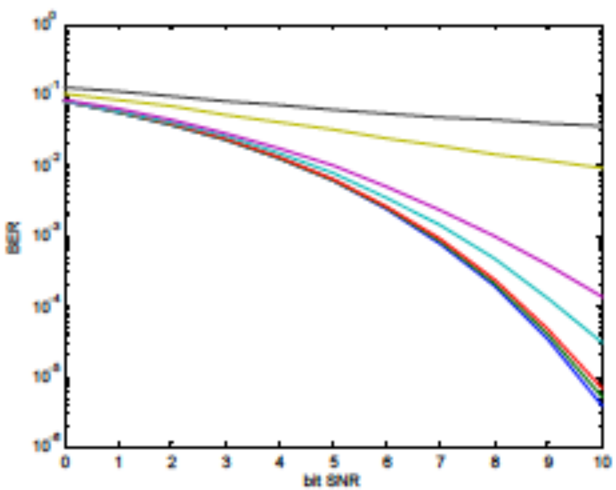
$$SINR$$

$$\frac{s_1(t)G}{\sum_{i=2}^{n}s_i(t)+n(t)}>1,\quad \frac{s_1(t)G}{n(t)}>>1$$

$$\frac{u_1(t)}{s_1(t)+\sum_{i=2}^{n}s_i(t)+\sum_{i=2}^{p}u_j(t)+\sum_{i=1}^{q}v_k(t)+J(t)+n(t)}<<1$$

Coordinated Jamming and Communications

- Processing gain: 255
- Total channel load: n + p + q + 1 (J); Total equivalent channel load N



- Performance results (curves)
  - Pe(enemy); N = 200
  - Pe(enemy); N = 100
  - Pe; n=20; Perfect jamming cancellation; No multi-user cancellation
  - Pe; n=10; Perfect jamming cancellation; No multi-user cancellation
  - Pe; Imperfect multi-user cancellation; Imperfect jamming cancellation
  - Pe; Imperfect multi-user cancellation; Imperfect jamming cancellation
  - Pe; Perfect multi-user cancellation; Perfect jamming cancellation

Coordinated Jamming and Communications

- Research issues and topics; Current activities
  - Jamming waveform design
    - Maximize jamming impact
    - Low complexity
    - Low cost (power)
    - Easy for cancellation
    - <u>Less impact of imperfect cancellation</u>
    - <u>Difficult for "anti-jamming"</u>
  - Performance evaluation
    - Combined jamming cancellation and multi-user cancellation
    - Impact of imperfect cancellation
    - Fading channel impact

5. Software Radio/Cognitive Radio and Implementation of CJamCom

- Concepts and architectures of SDR/CR
- SDR platforms and test beds
- CJamCom implementation strategies and test bed/demo

6. Recent cognitive radio research results

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