Wireless Network Coexistence Through Regular Channel Occupation

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Overview

- Motivation
- Related Work and Standards
- Proposed Method for IEEE 802.16 Coexistence
- Analytic Results
- Summary & Outlook

Motivation

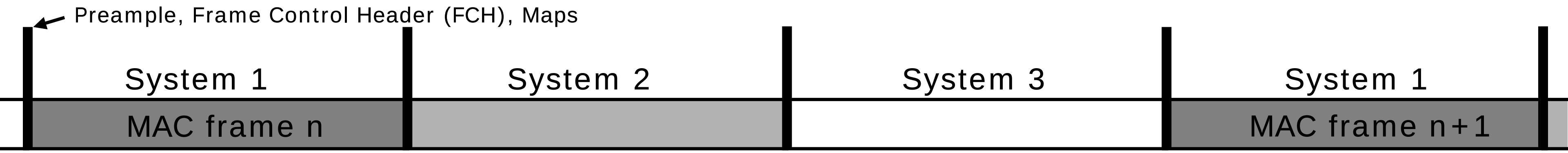
- Spectrum demand for wireless communication is growing
- All suitable frequency bands are assigned
- Operators deploying a new system in licensed bands have to:
  - Use a license they own
  - Buy a license from a license holder
  - Get a license for rededicated spectrum
- Alternative: license-exempt operation:
  - In bands dedicated for license-exempt operation
    - Ex. ISM: 2.4 GHz - 2.5 GHz, 5.725 GHz – 5.875 GHz
  - In licensed bands when license holder is absent
    - Non-exclusive license: 3.650 GHz – 3.700 GHz in US

⇒ Spectrum for license-exempt operation is available
⇒ Can be used at no/low costs
⇒ Requires no/less network planning

Related Work and Standards

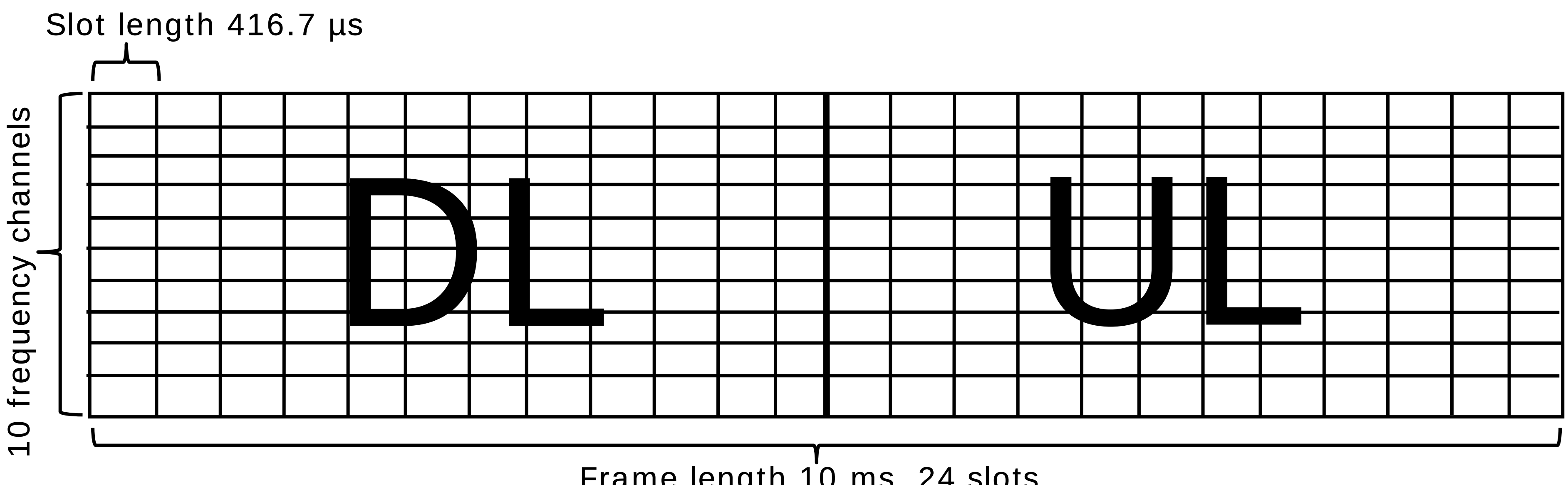
Examples for license-exempt operation:

- IEEE 802.11 (WLAN): CSMA/CA
  - Backoff reduces channel utilization
  - Unpredictable delays
  - Channel capacity depends on number of stations
- IEEE 802.15.1 (Bluetooth): Frequency hopping
  - Spectrum smoothing
  - Only possible for low power / low distance
- IEEE 802.16h (License-exempt WiMAX): TDMA
  - Exploit periodic MAC frame structure (5 ms – 20 ms frame duration)
  - Multiplex multiple systems in time domain
  - Delay depends on MAC frame lengths and system count



Related Work and Standards

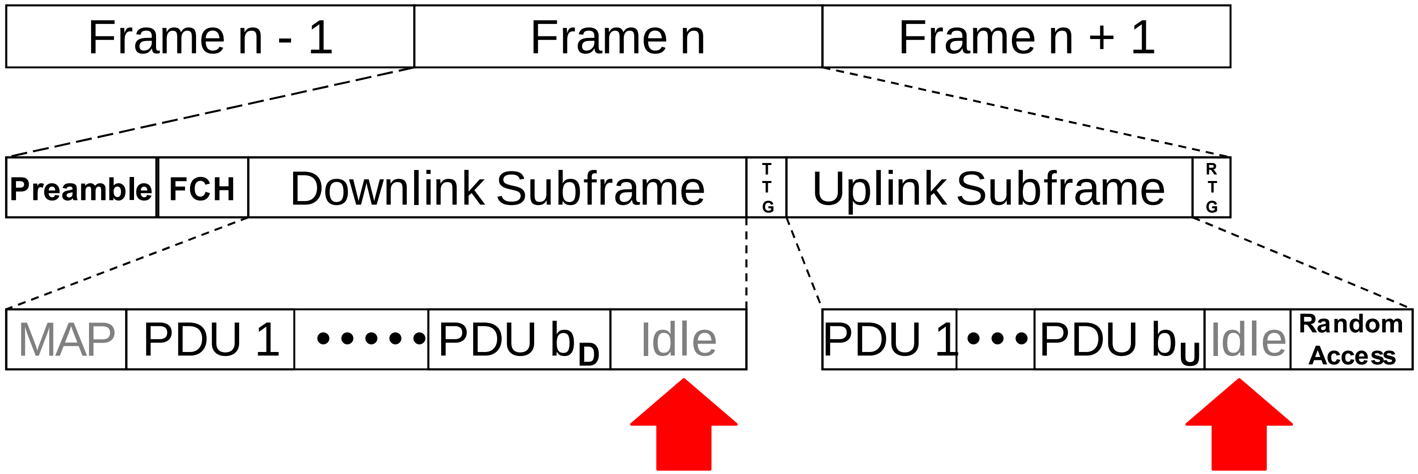
- Digital Enhanced Cordless Telecommunications (DECT)
  - 10 frequency channels
  - TDMA 24 slots, 12 per direction (DL/UL),
  - Possibly unsynchronized in time domain among different systems
  - Choose slot with lowest RSSI for new connection
  - Best performance if channel quality remains good in the future
    => Must be predictable / have low variance



Proposed Method

Can we multiplex IEEE 802.16 systems in time domain on smaller time scale than MAC frame duration?

IEEE 802.16 frame structure

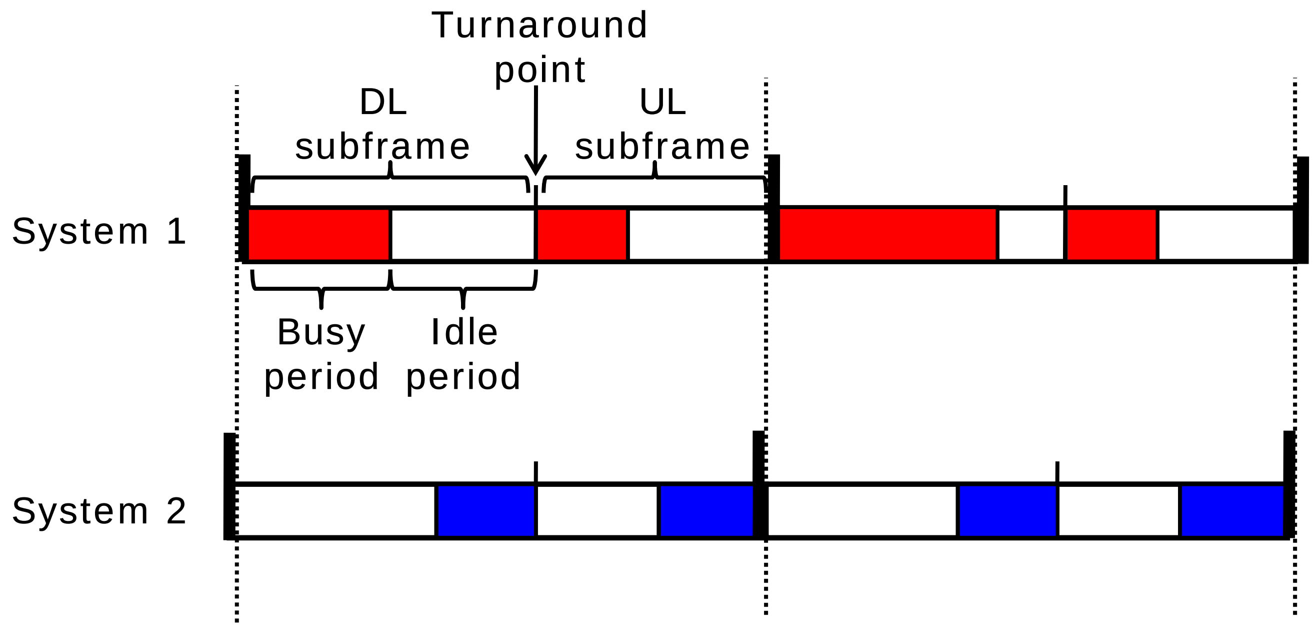


- Preamble, FCH, and Map at frame start
  - Whole frame could be lost for communication if not received
- Time division duplex (TDD)
- Downlink (DL) and uplink (UL) subframes
  - PDUs scheduled one after another
  - Idle periods at end of DL and UL subframe at low loads

Proposed Method

Idea: multiplex on subframe level

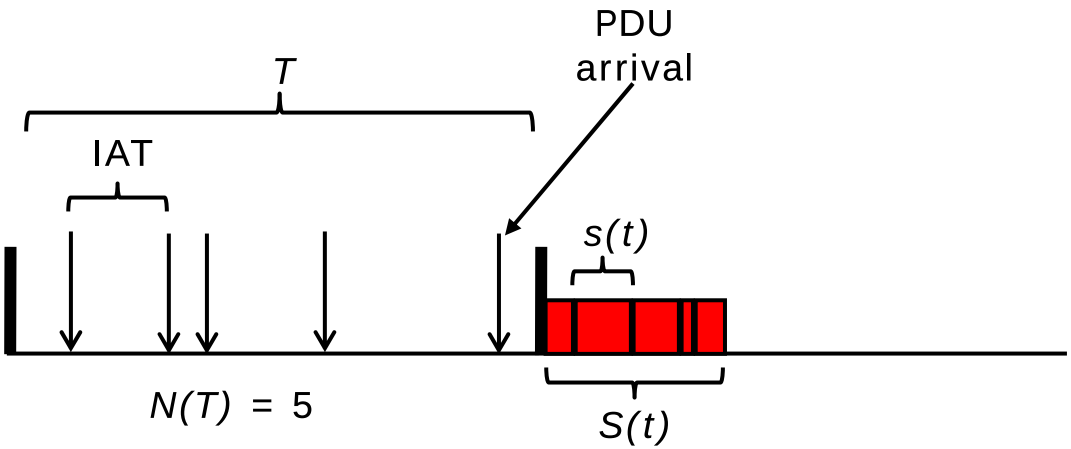
- Two system solution: fill subframes from front and back
- Precondition: systems have to synchronize DL/UL turnaround point
- Varying loads in each frame can cause simultaneous operation
- More than two systems: additional synchronization required

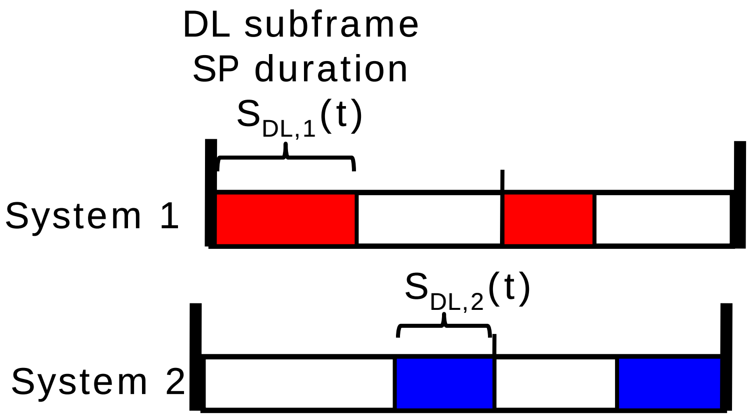


Analytic Results

Analytic results:

- Frame length is *T*
- *N(T)* is the counting process of PDU arrivals during *T*
- *N(T)* is Poisson distributed for neg. exponential PDU interarrival time
- *p(s(t))* is the processing time PDF of a PDU (transmission time)
- $p(S(t)|N(T) = n) = p(s(t))^{(n)}$ is the processing time PDF of n PDUs (**service period (SP) duration)**
- $p(S(t)) = \sum_{x=0}^{\infty} P(N(T)=x)\, p(S(t)\,|\,x) = \sum_{x=0}^{\infty} P(N(T)=x)\, p(s)^{(x)}$

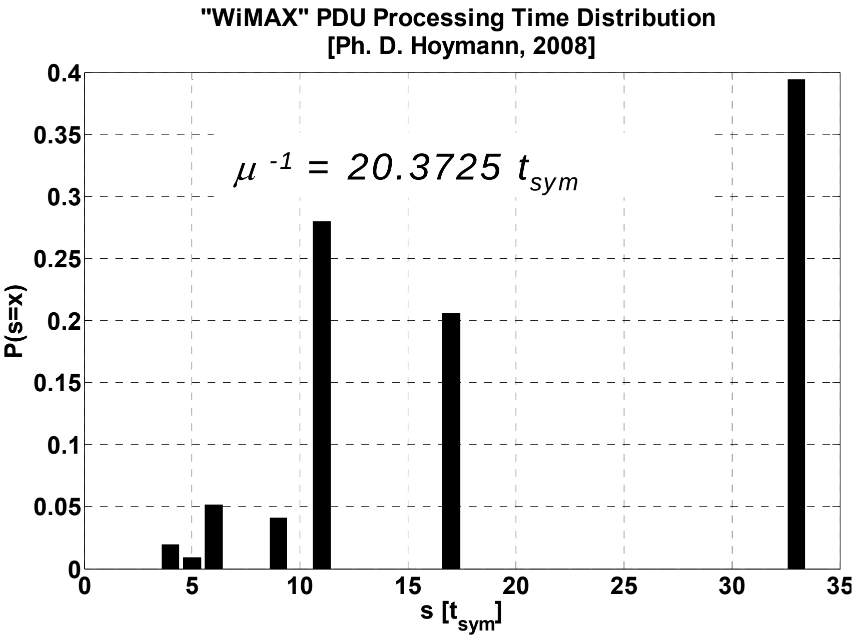


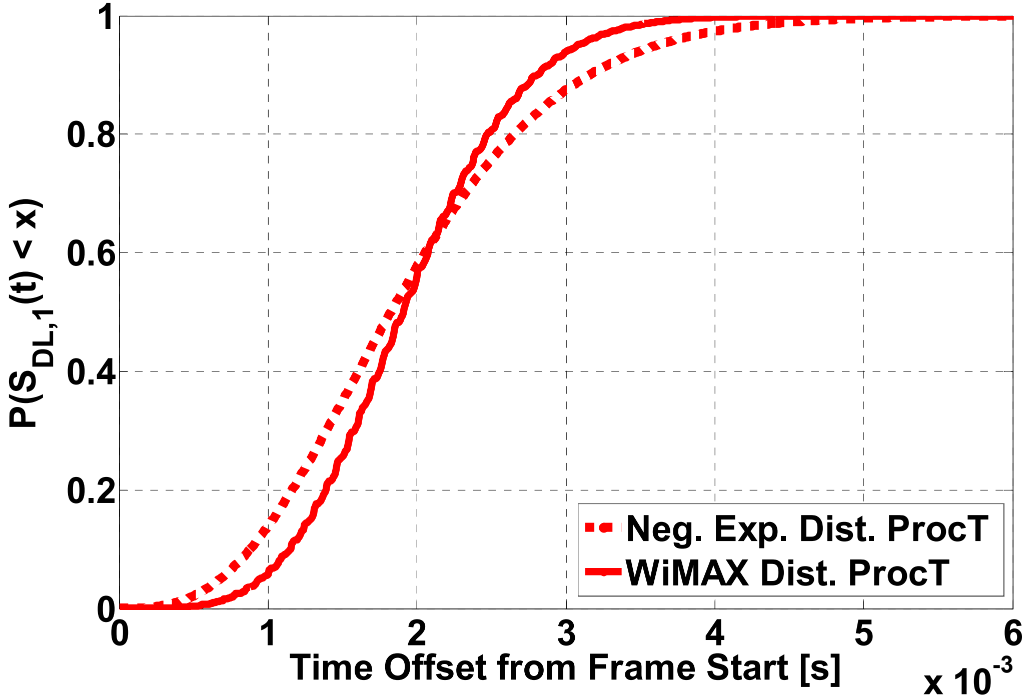


Analytic Results

Example: DL SP duration distribution for two different processing time distributions

- T = 10 ms = 720 symbols, symbol duration $t_{sym} \approx$ 13.9 µs
- Neg. exp. interarrival time
- Processing time: neg. exp. / “WiMAX PHY Modes”, $\mu^{-1} = 20.3725\ t_{sym}$
- Traffic load $\rho = 0.375$
- Zero size Preamble, FCH, Map

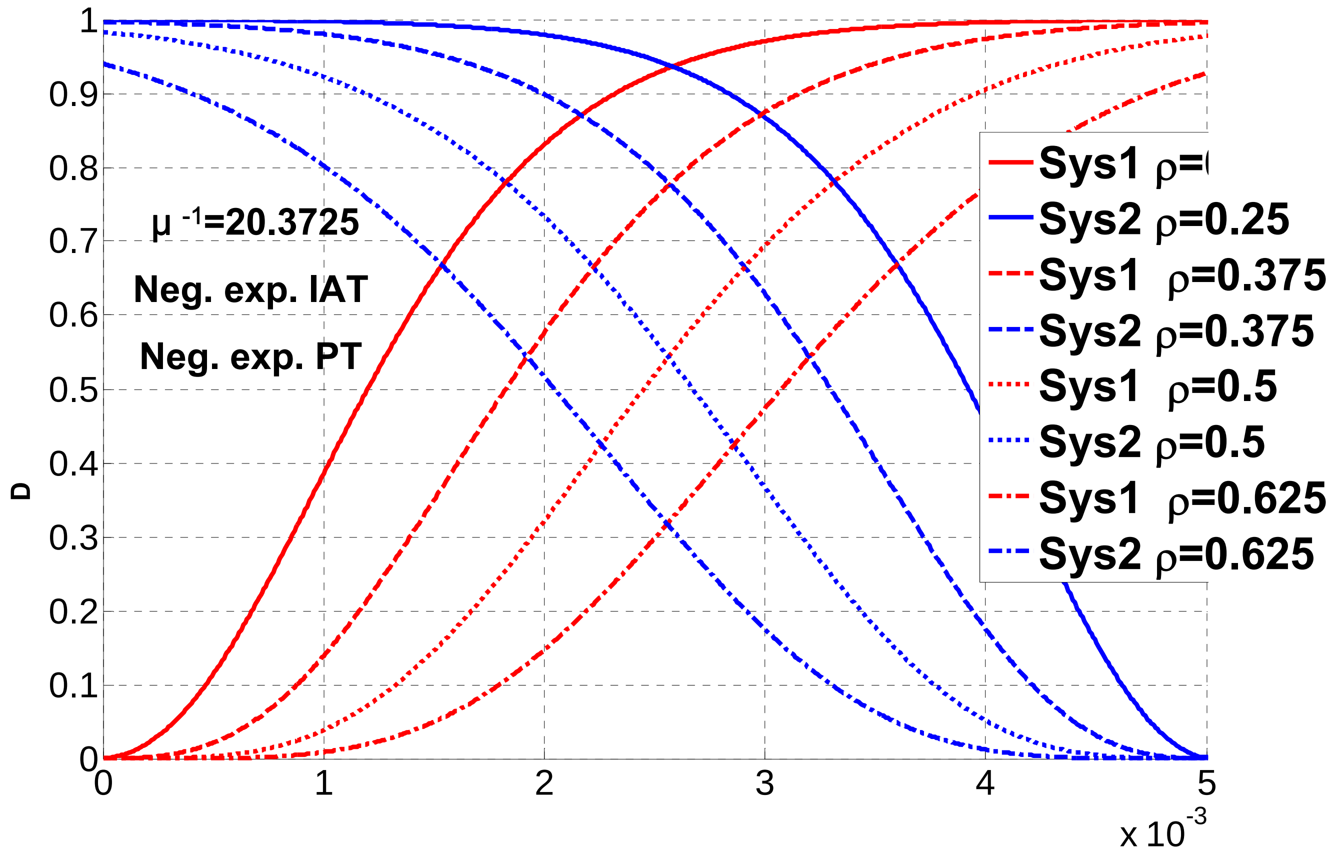




Analytic Results

Influence of offered load:

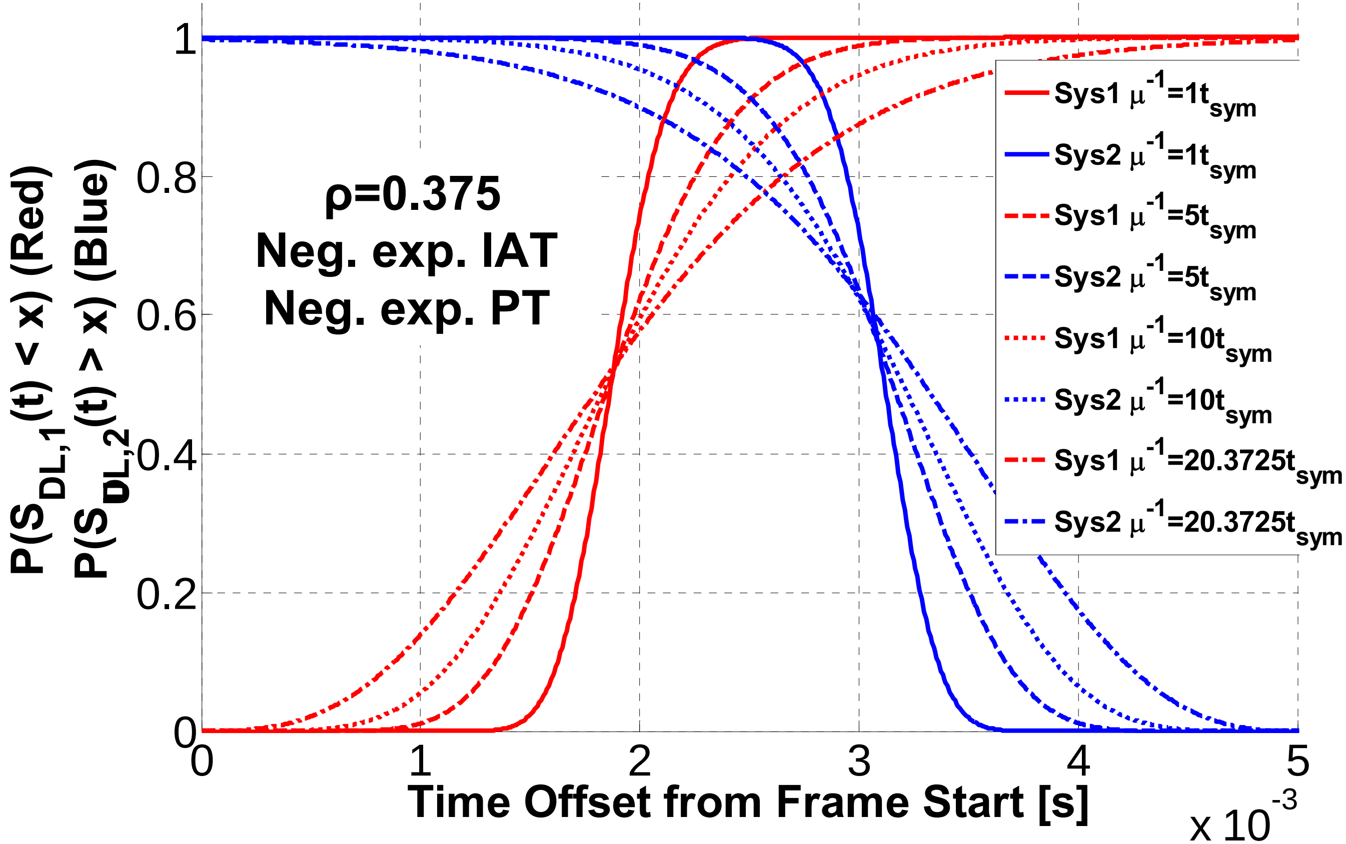
- Assumption: UL subframe starts at $T/2$
- Increasing load increases mean service period duration



Analytic Results

Influence of mean PDU transmission time:

- Variance decreases as transmission time decreases (shorter PDU, better PHY mode)



Analytic Results

What is the probability

of simultaneous operation?

$$P_{Coll} = P(S_{DL,1}(t) \geq S_{DL,2}(\tau))$$

$$= \int_0^T \int_0^t p(S_{DL,1}(t), S_{DL,2}(\tau))dtd\tau$$

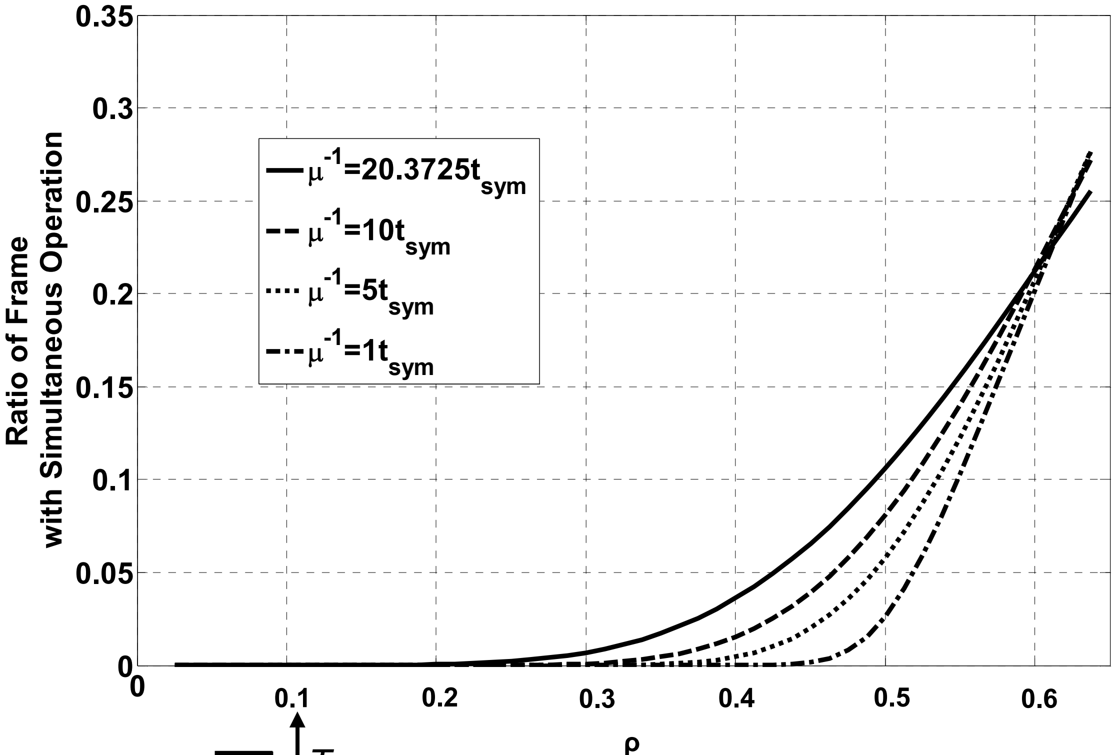
$$= \int_0^T \int_0^t p(S_{DL,1}(t))\, p(S_{DL,2}(\tau))dtd\tau$$

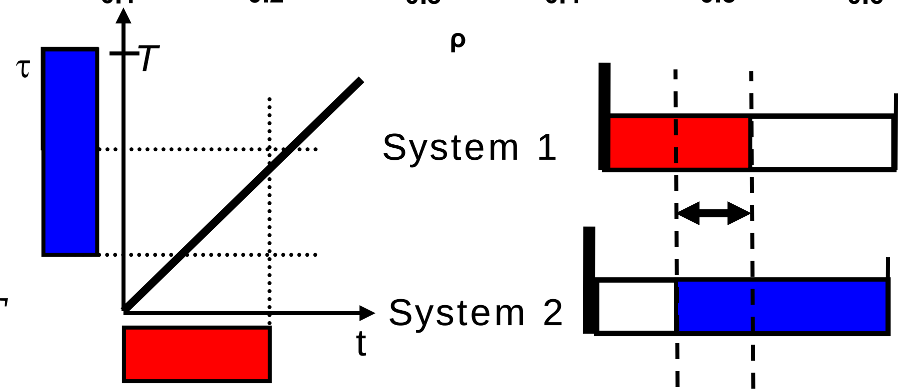
What is the expected

duration relative to *T*?

$$2E_{P_{Coll}}[t-\tau]/T$$

$$= 2\int_0^T \int_0^t p(S_{DL,1}(t))\, p(S_{DL,2}(\tau))(t-\tau)dtd\tau / T$$





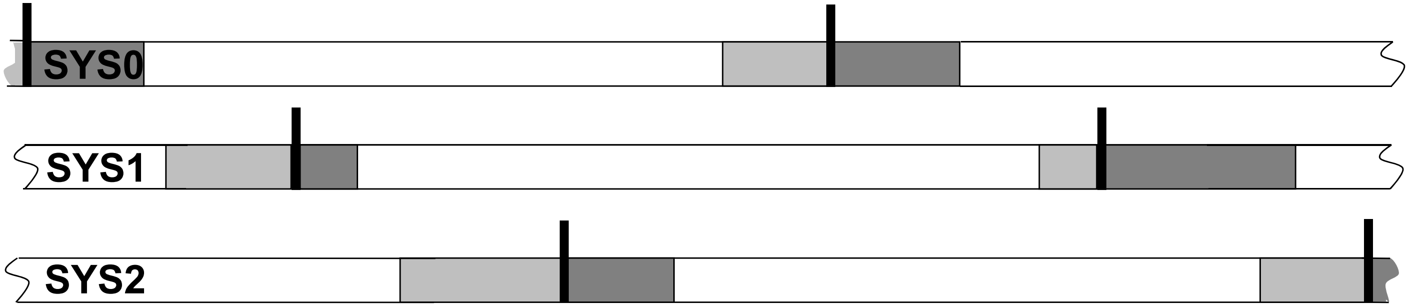
Summary & Outlook

Summary:

- Presented scheme assures predictable channel occupation
- Simultaneous operation is possible but the probability could be low enough for some applications
- Traffic classes are possible when scheduling at offsets with different collision probabilities

Outlook:

- Compare with 802.16h frame multiplexing
- Solutions for more than two systems
- Include node positions and SINR in model



Thank you for your attention !

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