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ILLINOIS INSTITUTE OF TECHNOLOGY

Semantic Models for Labeling Spectrum Data

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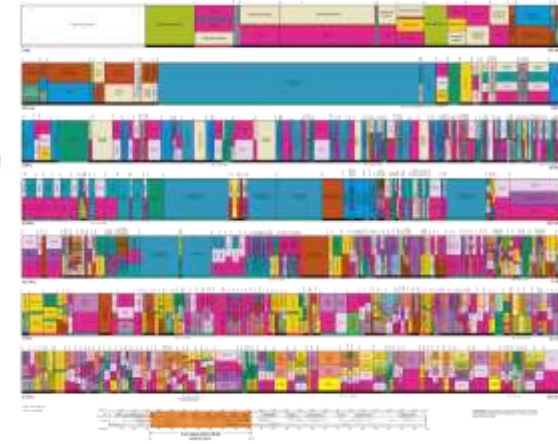


Motivation

- Growing demand for wireless spectrum
 - New and expanding services
- Spectrum finite resource
 - Measured in frequency, time, space
 - Fully allocated but not fully utilized
- Spectrum sharing necessary
- How to identify sharing opportunities?
 - Understanding dynamics of spectrum use critical
 - Measurement and analysis of spectrum use needed

UNITED STATES FREQUENCY ALLOCATIONS THE RADIO SPECTRUM

Band	Color
118.0 - 137.0 MHz	Blue
137.0 - 174.0 MHz	Green
174.0 - 220.0 MHz	Yellow
220.0 - 230.0 MHz	Orange
230.0 - 245.0 MHz	Red
245.0 - 256.0 MHz	Purple
256.0 - 270.0 MHz	Light Blue
270.0 - 283.5 MHz	Light Green
283.5 - 300.0 MHz	Light Yellow
300.0 - 316.0 MHz	Light Orange
316.0 - 330.0 MHz	Light Red
330.0 - 348.0 MHz	Light Purple
348.0 - 360.0 MHz	Light Blue
360.0 - 375.0 MHz	Light Green
375.0 - 390.0 MHz	Light Yellow
390.0 - 400.0 MHz	Light Orange
400.0 - 420.0 MHz	Light Red
420.0 - 438.0 MHz	Light Purple
438.0 - 450.0 MHz	Light Blue
450.0 - 470.0 MHz	Light Green
470.0 - 480.0 MHz	Light Yellow
480.0 - 500.0 MHz	Light Orange
500.0 - 512.0 MHz	Light Red
512.0 - 525.0 MHz	Light Purple
525.0 - 540.0 MHz	Light Blue
540.0 - 562.0 MHz	Light Green
562.0 - 578.0 MHz	Light Yellow
578.0 - 608.0 MHz	Light Orange
608.0 - 630.0 MHz	Light Red
630.0 - 648.0 MHz	Light Purple
648.0 - 660.0 MHz	Light Blue
660.0 - 688.0 MHz	Light Green
688.0 - 714.0 MHz	Light Yellow
714.0 - 744.0 MHz	Light Orange
744.0 - 762.0 MHz	Light Red
762.0 - 786.0 MHz	Light Purple
786.0 - 810.0 MHz	Light Blue
810.0 - 834.0 MHz	Light Green
834.0 - 864.0 MHz	Light Yellow
864.0 - 894.0 MHz	Light Orange
894.0 - 918.0 MHz	Light Red
918.0 - 936.0 MHz	Light Purple
936.0 - 960.0 MHz	Light Blue
960.0 - 984.0 MHz	Light Green
984.0 - 1000.0 MHz	Light Yellow





IIT Spectrum Observatory

- Continually collecting spectrum measurements
 - Multiple antennas + spectrum analyzer
 - Energy detection sensing
- General purpose wideband monitoring since 2007
 - 30 MHz – 6 GHz
 - Lower resolution
 - Each sweep takes ~ minute
 - ~ 93 MB data/day
- Special purpose monitoring in Land Mobile Radio (LMR) bands since Oct 2017
 - Public Safety communications
 - Federal, state and local
 - Higher resolution monitoring
 - Multiple sweeps/sec
 - ~ 16 GB data/day



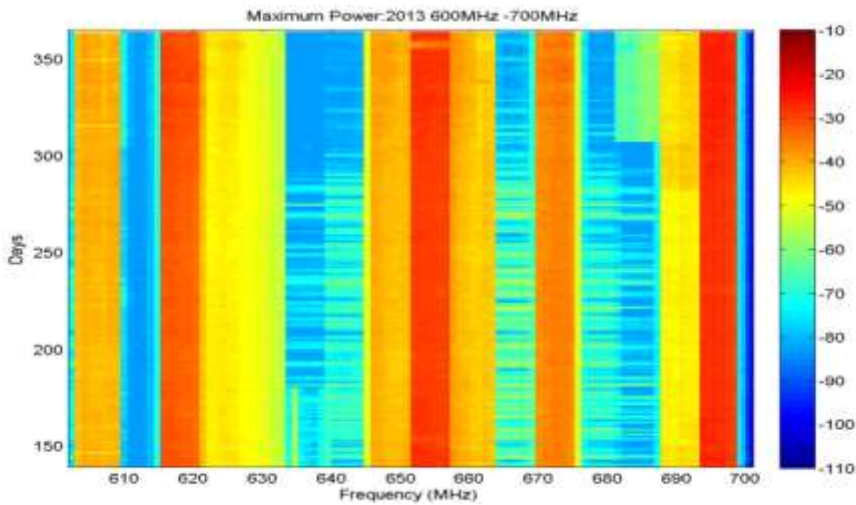


Multi-band Spectrum Measurements

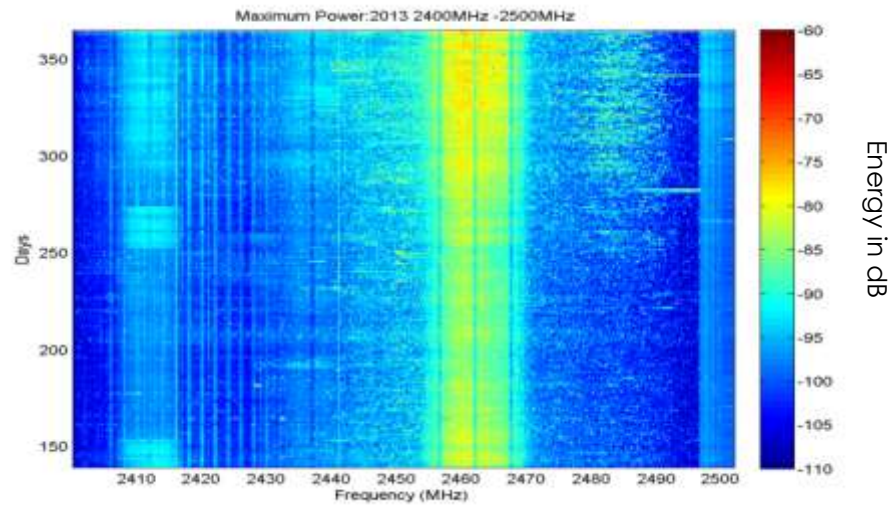
- Complex spatio-temporal datasets
- Require specialized domain knowledge to collect, analyze and interpret
 - Knowledge different for each band/channel
 - Different transmitters
 - Different uses
- Very time consuming to process and analyze
- Visual inspection of spectrograms or waterfall charts typical



Example Spectrograms/Waterfall Charts



600 MHz television bands during 2013

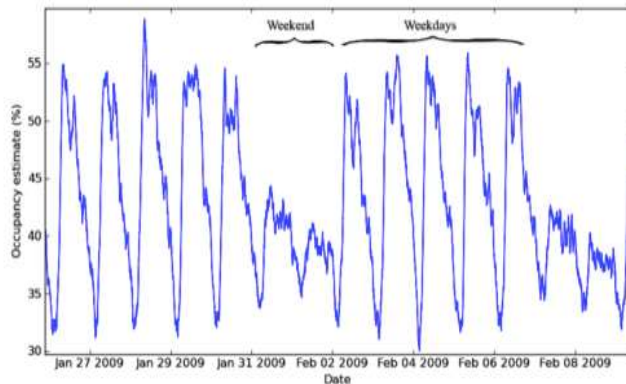


2.4 GHz Band during 2013

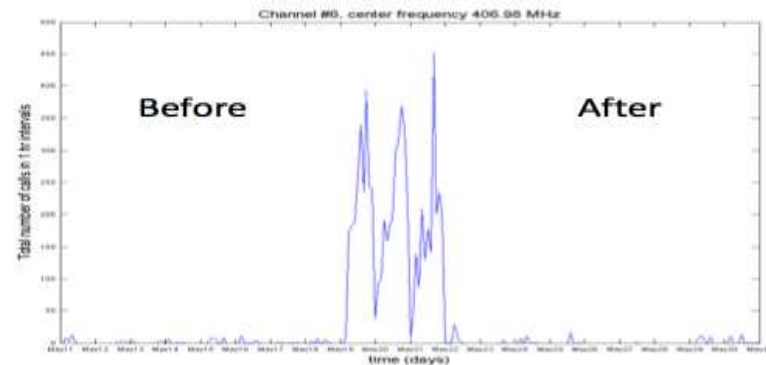


Focus on Public Safety Bands

- Interest in sharing these bands
 - Between public safety agencies
 - More general use
- Significant contextual information available
 - How bands configured for use
 - Human protocols around communication
 - Activity/events that drive communication



Two week plot of spectrum occupancy in the 450 MHz LMR band



Call rate in 406 MHz band around NATO Summit



Approach

- Goal is to understand the dynamics of underutilized public safety spectrum
 - Need to protect critical public safety communication
 - How and why does spectrum usage change?
 - Need to understand spectrum use during events w/significant public safety communication
 - Focus on changes driven by events
- Initial challenge is to identify data of interest for analysis
- Approach is to use the spectrum measurements to model spectrum use and model contextual information that can help explain spectrum usage
 - Statistical and semantic models
 - Utilize semantics and reasoning to label statistical data
 - Want to be able to query spectrum data to identify sets of events with shared characteristics



Case Study Chicago Marathon

- Focus on Chicago Police Department (CPD) spectrum
- Chicago Marathon (planned event)
 - 26.2 mile course
 - 22 neighborhoods
 - 45,000 runners
 - Roads closed
 - Additional bus/train services for traffic





CPD Spectrum Organization

- Geographic organization
 - 25 Districts
 - 13 Zone dispatch channels
 - Communication within zone
 - IIT Spectrum Observatory is in 21st District which is part of Zone 5

- 8 Citywide channels
 - Each channel has general set of uses



CHICAGO POLICE DEPARTMENT RADIO COMMUNICATIONS SYSTEMS:

CITYWIDE RADIO CHANNELS

CW#	FREQ	ZONE	USE
1	460.125	(173.8)	MAJOR AUTO ACCIDENT, TRAFFIC, GANGS, PUBLIC HOUSING, CTA
2	460.175	(123.0)	DETECTIVES, CANINE, MOUNTED, DEPUTIES, IAD, VICE, ET'S
3	460.275	(141.3)	WANTED FLASHES, MAINTENANCE, FILMS, ADMIN
4	460.325	(192.8)	HUMAN RELATIONS, SCHOOLS, YOUTH, MARINE
5	460.350	(097.4)	SUBWAY COMM SYSTEM / EMER OR EVENT SECONDARY
6	460.250	(162.2)	EMER OR EVENT PRIMARY / ALTERNATE ZONE DISPATCH
7	460.300	(131.8)	COMMAND, PHONE PATCH, PAGERS, BEEPERS
8	460.525	(179.9)	CHANNEL "FIVE" SIMPLEX UNIT TO UNIT SHORT RANGE

ZONE DISPATCH CHANNELS

ZONE	FREQ	ZONE	DISTRICTS
1	460.475	(107.2)	16TH / 17TH DISTRICTS
2	460.050	(127.3)	19TH / 23RD DISTRICTS
3	460.225	(110.9)	13TH / 14TH DISTRICTS
4	460.150	(114.8)	1ST / 18TH DISTRICTS
5	460.500	(167.9)	2ND / 21ST DISTRICTS
6	460.400	(156.7)	7TH / 8TH DISTRICTS
7	460.075	(146.2)	3RD DISTRICT
8	460.200	(136.5)	4TH / 6TH DISTRICTS
9	460.025	(091.5)	5TH / 22ND DISTRICTS
10	460.100	(151.4)	10TH / 11TH DISTRICTS
11	460.375	(186.2)	20TH / 24TH DISTRICTS
12	460.425	(094.8)	15TH / 25TH DISTRICTS
13	460.450	(103.5)	9TH / 12TH DISTRICTS

SPECIALIZED UNITS

472.9375	MASS TRANSIT (127.3)		
155.370	POINT AID (000.0)		
155.475	ISPERN RADIOS F1 (000.0)		
154.850	ISPERN RADIOS F2 (000.0)		
156.000	AID WITH METRO ENFORCEMENT GROUPS	(000.0)	(DEFUNCT?)

DATA SYSTEM

865.9375	865.9625	866.1875	866.2125	866.3375	866.5625	866.5875
866.6750	866.8125	867.1000	867.1750	867.5375	867.6375	867.6500
867.7375	867.7625	868.1000	868.2250	868.3000	868.3250	868.3500
868.5750	868.6750	868.7250	868.8000	868.8250		





Semantic modeling

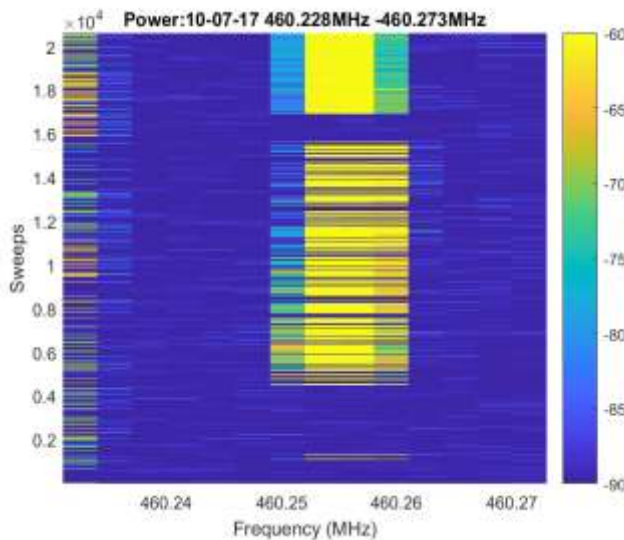
- CPD Spectrum organization relationships
 - Neighborhood -> Districts
 - Districts -> Zones
 - Zone -> Frequency (channel)
 - Citywide channel -> uses
- Events (planned)
 - Location/Neighborhood
 - Date
 - Type of event
- Encoded using SWI-Prolog



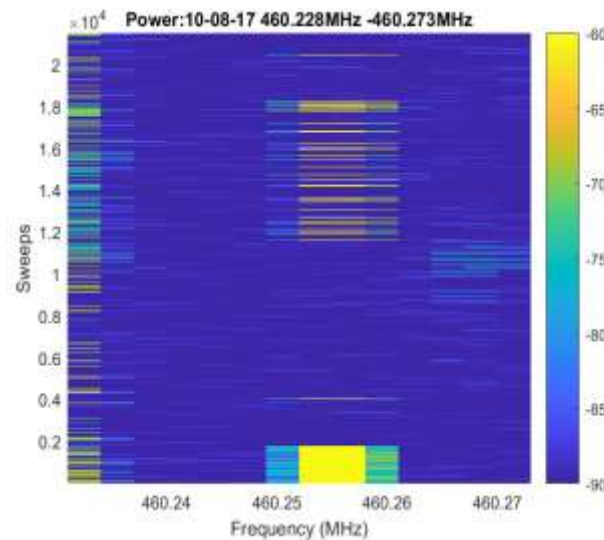
Statistical modeling

- Simple threshold

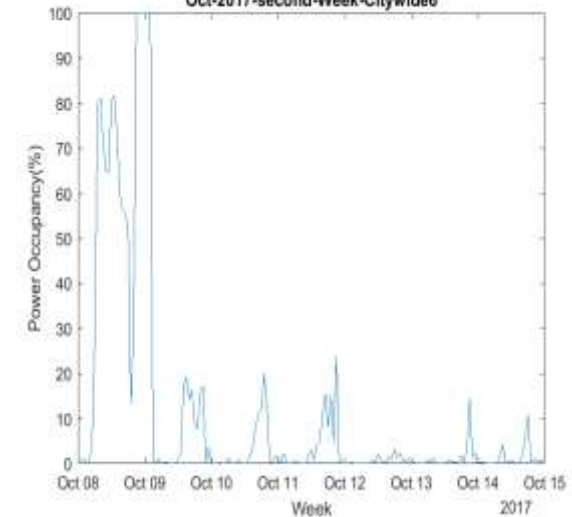
11pm 10/7 – 11pm 10/8



11pm 10/8 – 11pm 10/9



Oct-2017-second-Week-Citywide6



Chicago Police Citywide channel 6 (460.25 MHz)



Is there an event driving increased CPD spectrum usage on Oct 8?



`checkEvent('October 8,2017')`

Event Found:

Chicago Marathon

Check Channels:

zone_2

zone_5

zone_13

zone_4

citywide_1

citywide_5

citywide_6



Conclusion

- Spectrum measurements form complex spatio-temporal data set
 - Challenging to find data of interest
 - Similar characteristics
 - Statistical information/models not adequate to understand spectrum usage
 - Context necessary
- Semantic modeling can be used to represent contextual knowledge
- Reasoning can be used to link statistical and contextual information through labels
- CPD Public Safety case study provides initial proof-of-concept for approach
 - Simple models



Ongoing Work

- More complex models
 - Spectrum measurements
 - Capture usage patterns
 - Daily, weekly, seasonal variations
 - Multichannel communications
 - Context
 - Expand events
 - Planned, unplanned (emergency)
 - Human protocols for public safety
- Automate information collection
- Automate labeling of spectrum measurements



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Questions?

Thank you!

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