Low-Rate, Flow-Level Periodicity Detection

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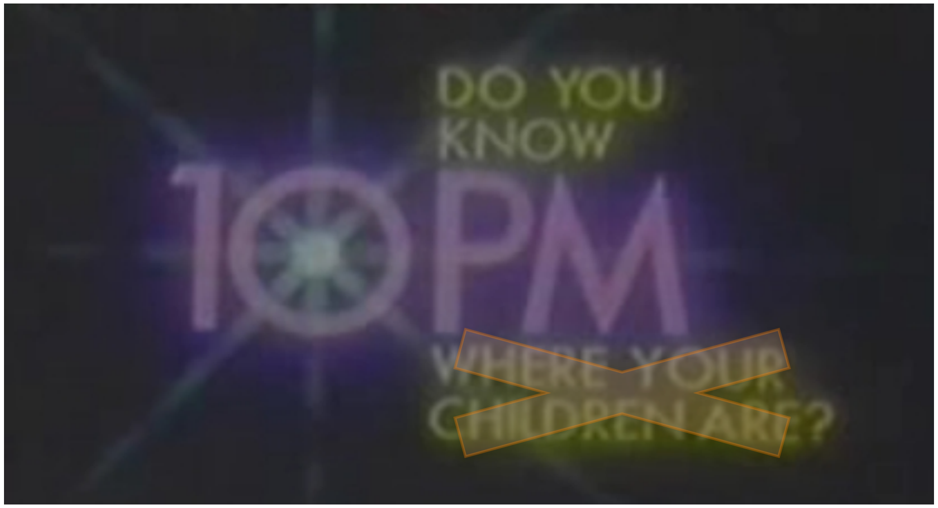
MOTIVATION



It's 10pm, do you know what your computer's doing??

- Automatic computer initiated communication
- More complex systems = more computer initiated communication

LOW-RATE AND PERIODIC CONNECTIONS

- Subset of computer initiated: periodic connections
- Find periodic series in aggregate traffic with signal processing
- Flow-level
  - Event = connection start
  - Our methods could apply to many other events
- Low-Rate: 2s to several hours (Days? Weeks?)

APPLIES TO MANY APPLICATIONS

- Many applications are low-rate periodic:
  - User services (30-120 mins)
    - WeatherEye
    - MacOS Dashboard apps
    - Clock applet in Gnome (Linux)
  - RSS News Feeds (30-60mins)
  - Web Counters (5-30mins)
    - http refresh
  - Peer-to-Peer (~20-30 mins)
  - Adware (minutes to hours)
  - Spyware
  - Botnet Command & Control

CONTRIBUTIONS

- Low-rate periodicity as a phenomenon of interest
- Low-rate periodicity prevalent in real-world traffic
- Novel method for detection
- Demonstration of applications
  - Self-surveillance (GI paper)
  - Pre-filtering for detection triage

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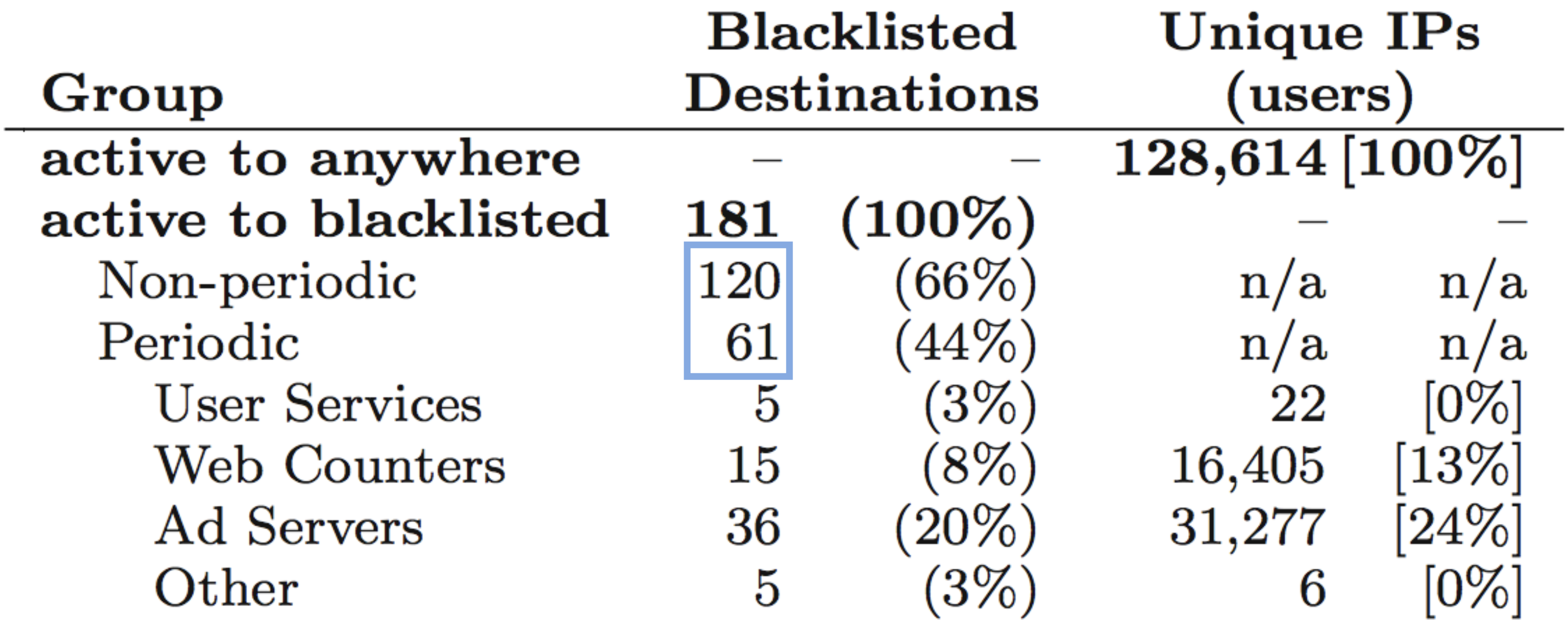
ARE PERIODIC APPLICATIONS PREVALENT?

- Pick an interesting application
  - Malware!
- How do we confirm periodic malware exists at USC?
  - No payload
  - Blacklisted sites
  - Aggregate traffic (groups of ~20)
  - Determine which groups show periodic communication

HOW PREVALENT IS PERIODIC COMMUNICATION?



Group	Blacklisted Destinations		Unique IPs (users)	
active to anywhere	–	–	**128,614**	**[100%]**
active to blacklisted	**181**	**(100%)**	–	–
Non-periodic	120	(66%)	n/a	n/a
Periodic	61	(44%)	n/a	n/a
User Services	5	(3%)	22	[0%]
Web Counters	15	(8%)	16,405	[13%]
Ad Servers	36	(20%)	31,277	[24%]
Other	5	(3%)	6	[0%]

Nearly a third show periodic behavior!
∴ We can find 1/3 blacklisted servers on our network looking at periodic behavior as a first pass.

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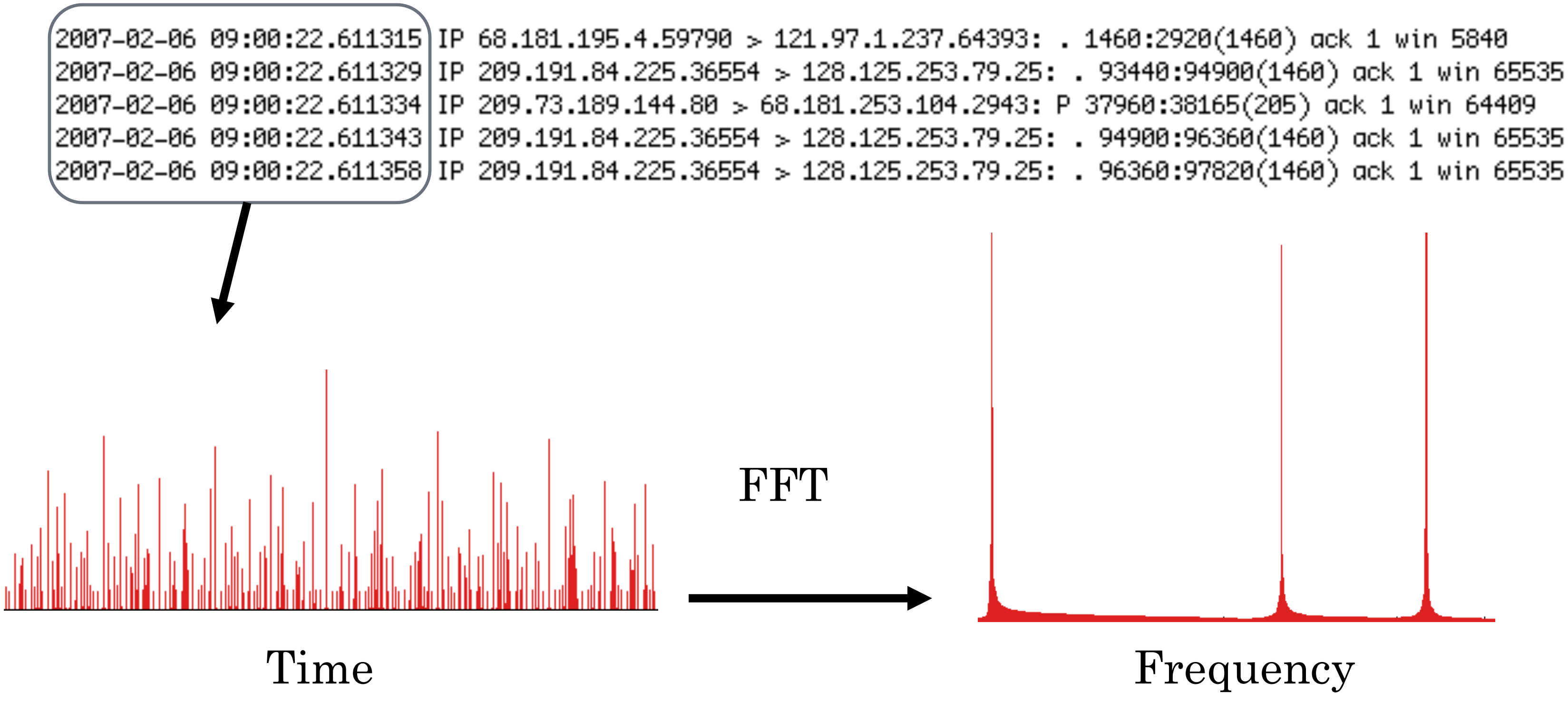
TYPICAL APPROACH TO FINDING PERIODIC EVENTS

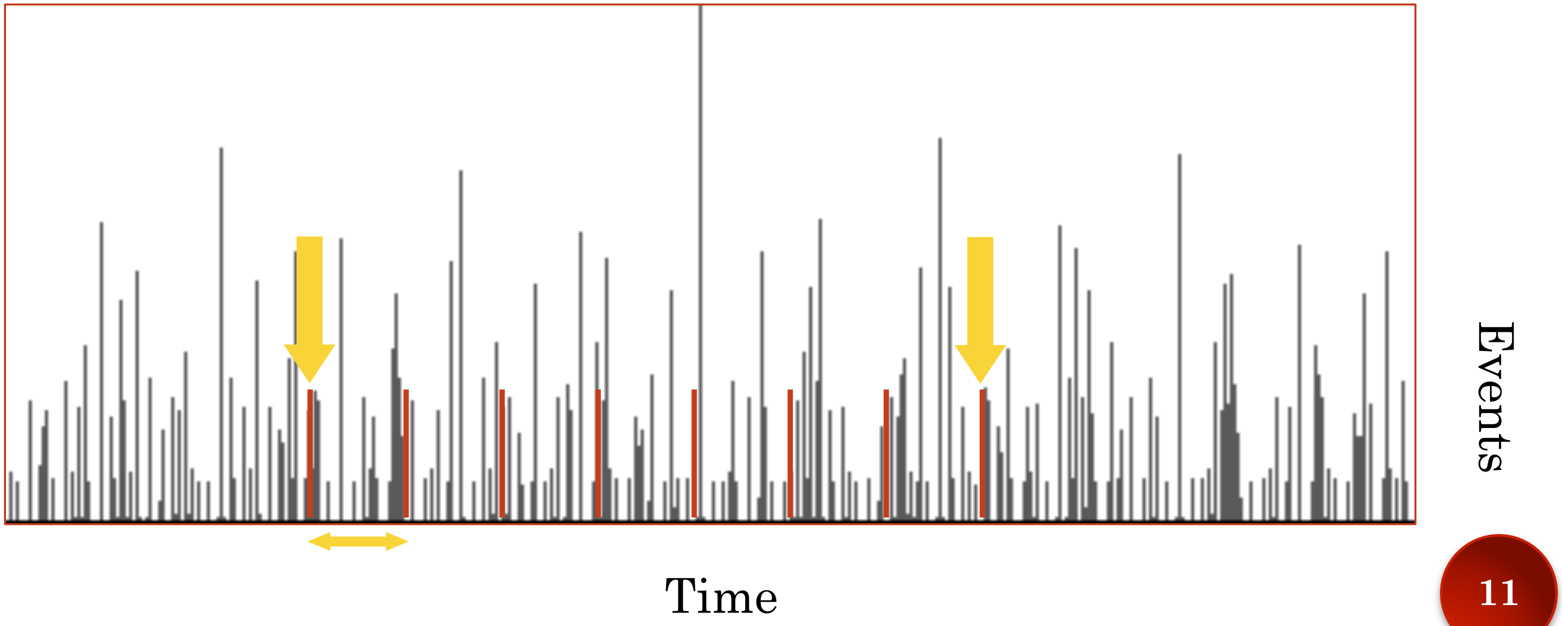
Network events > time series > FFT >analysis



```
2007-02-06 09:00:22.611315 IP 68.181.195.4.59790 > 121.97.1.237.64393: . 1460:2920(1460) ack 1 win 5840
2007-02-06 09:00:22.611329 IP 209.191.84.225.36554 > 128.125.253.79.25: . 93440:94900(1460) ack 1 win 65535
2007-02-06 09:00:22.611334 IP 209.73.189.144.80 > 68.181.253.104.2943: P 37960:38165(205) ack 1 win 64409
2007-02-06 09:00:22.611343 IP 209.191.84.225.36554 > 128.125.253.79.25: . 94900:96360(1460) ack 1 win 65535
2007-02-06 09:00:22.611358 IP 209.191.84.225.36554 > 128.125.253.79.25: . 96360:97820(1460) ack 1 win 65535
```

WHAT ARE WE LOOKING FOR?

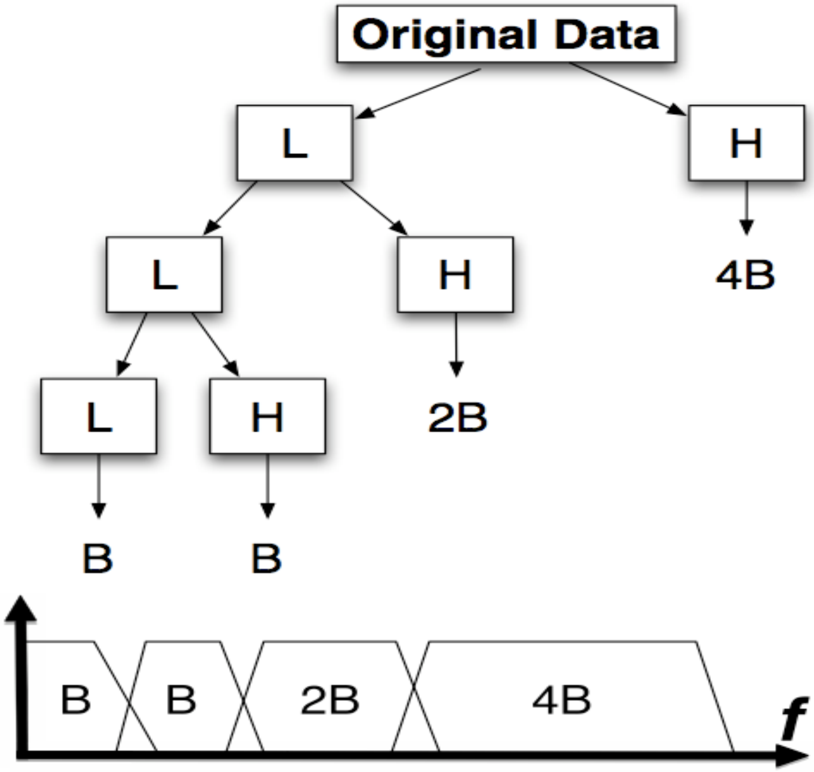
- Given network data:
  - Is there a periodic event?
  - If so, what is the period?
  - Location in time: Start/Stop of events

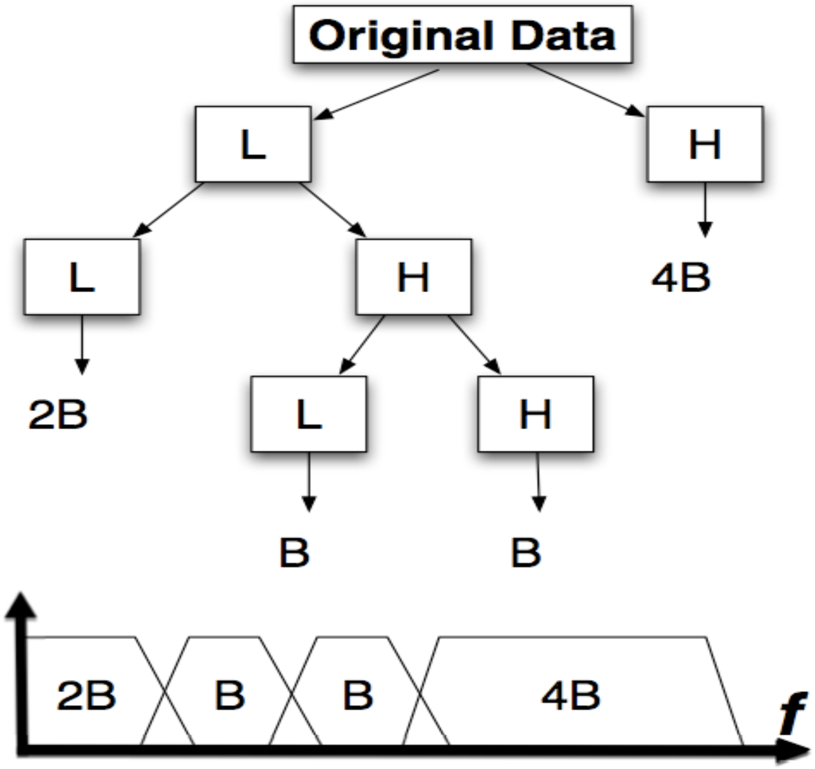


GOALS AND DESIGN

Preserve time information	wavelets
Simple representation and implementation	Haar wavelet basis: differencing/averaging match for sharp changes
Low-rate periods	**Coarse time bins ~1min+**
Large range of frequencies	Iterative filter-bank **Full decomposition**

MULTIRESOLUTION ANALYSIS: SINGLE PATH

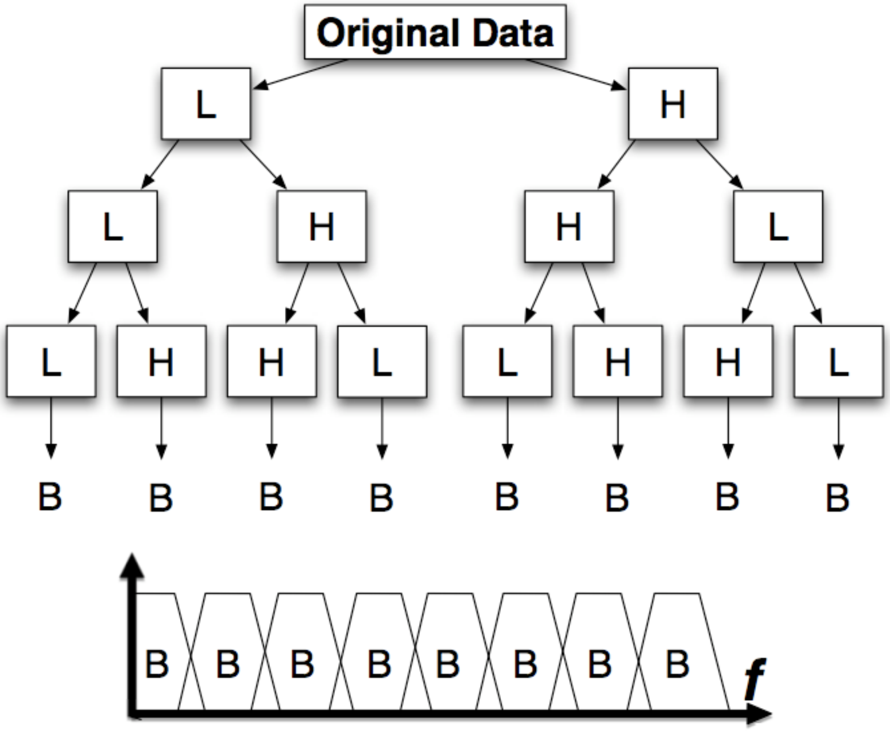




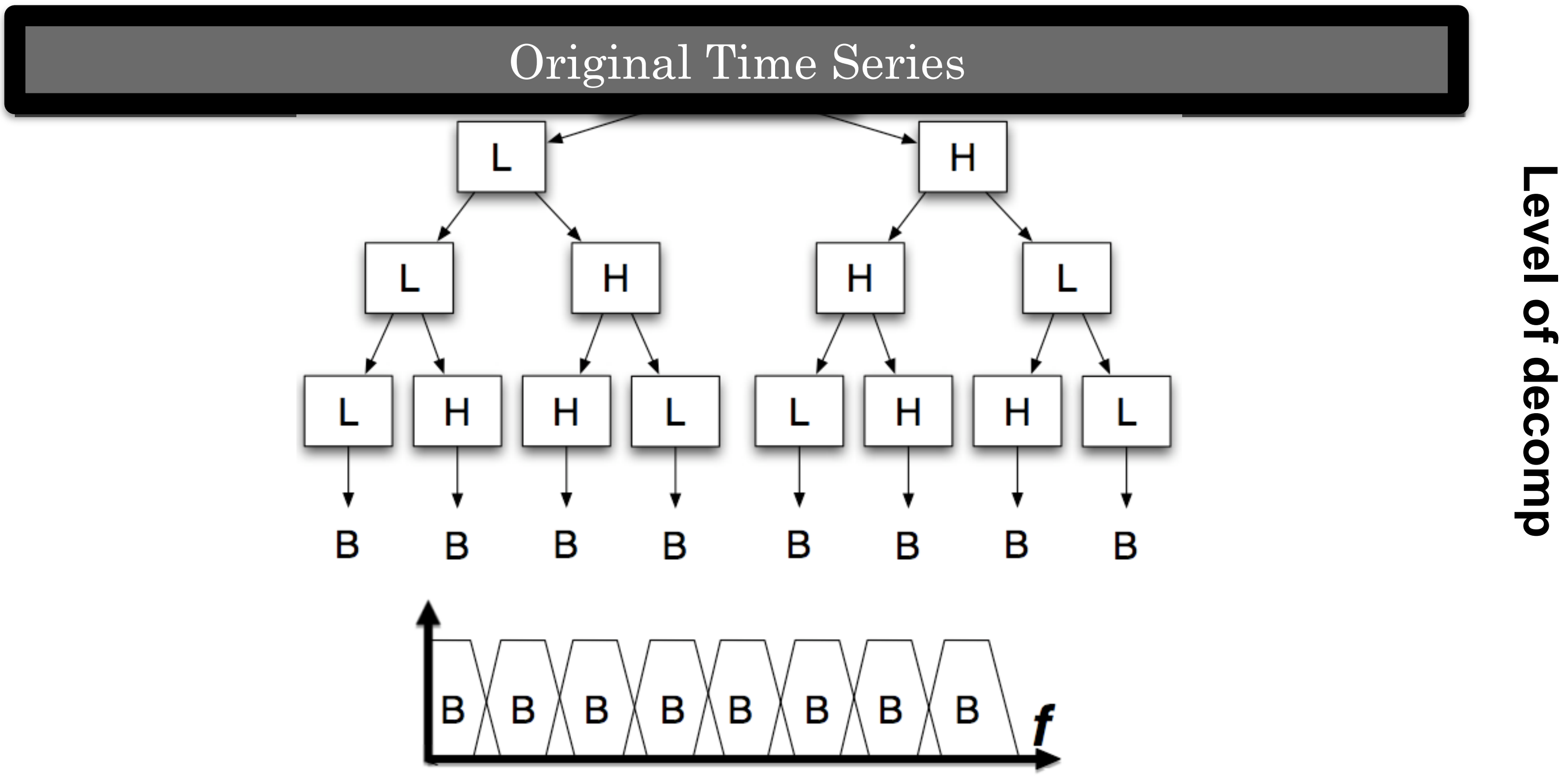
Different paths give different frequency splits.
Can focus in on a frequency range, if we know which we want *a priori*.

MULTIRESOLUTION ANALYSIS: FULL

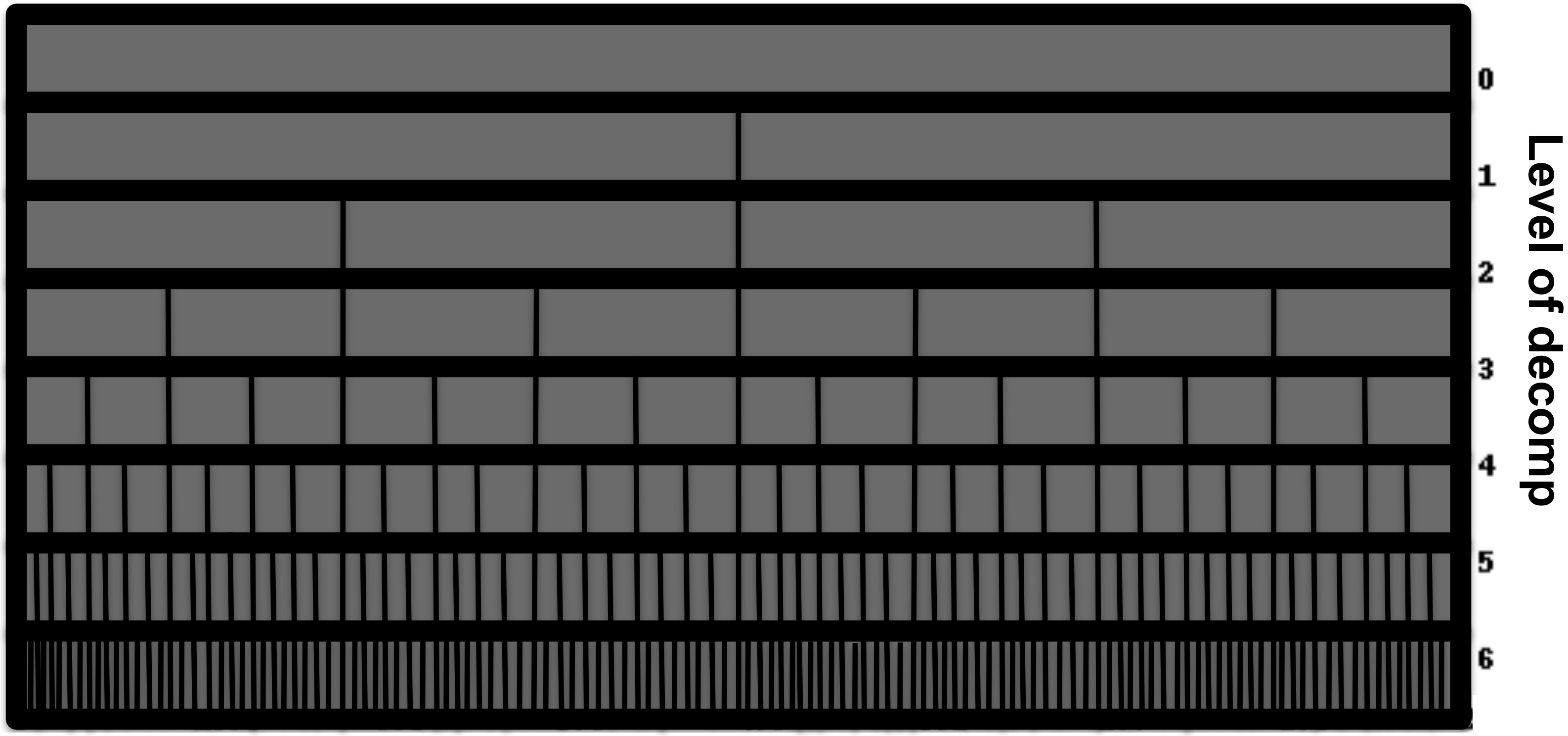
- Full decomposition
- We examine multiple frequency ranges
- Level of decomp determined by length and sample rate of original data



VISUALIZATION



VISUALIZATION



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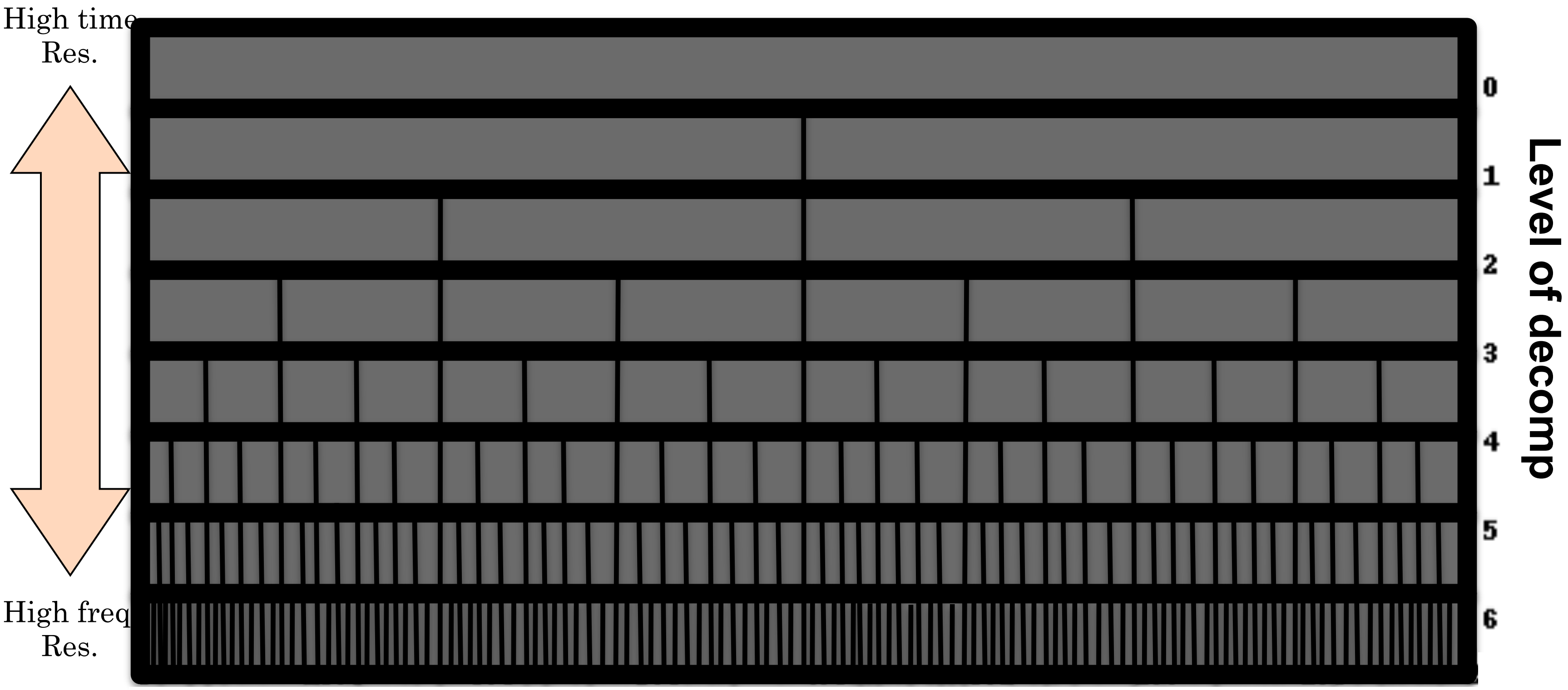

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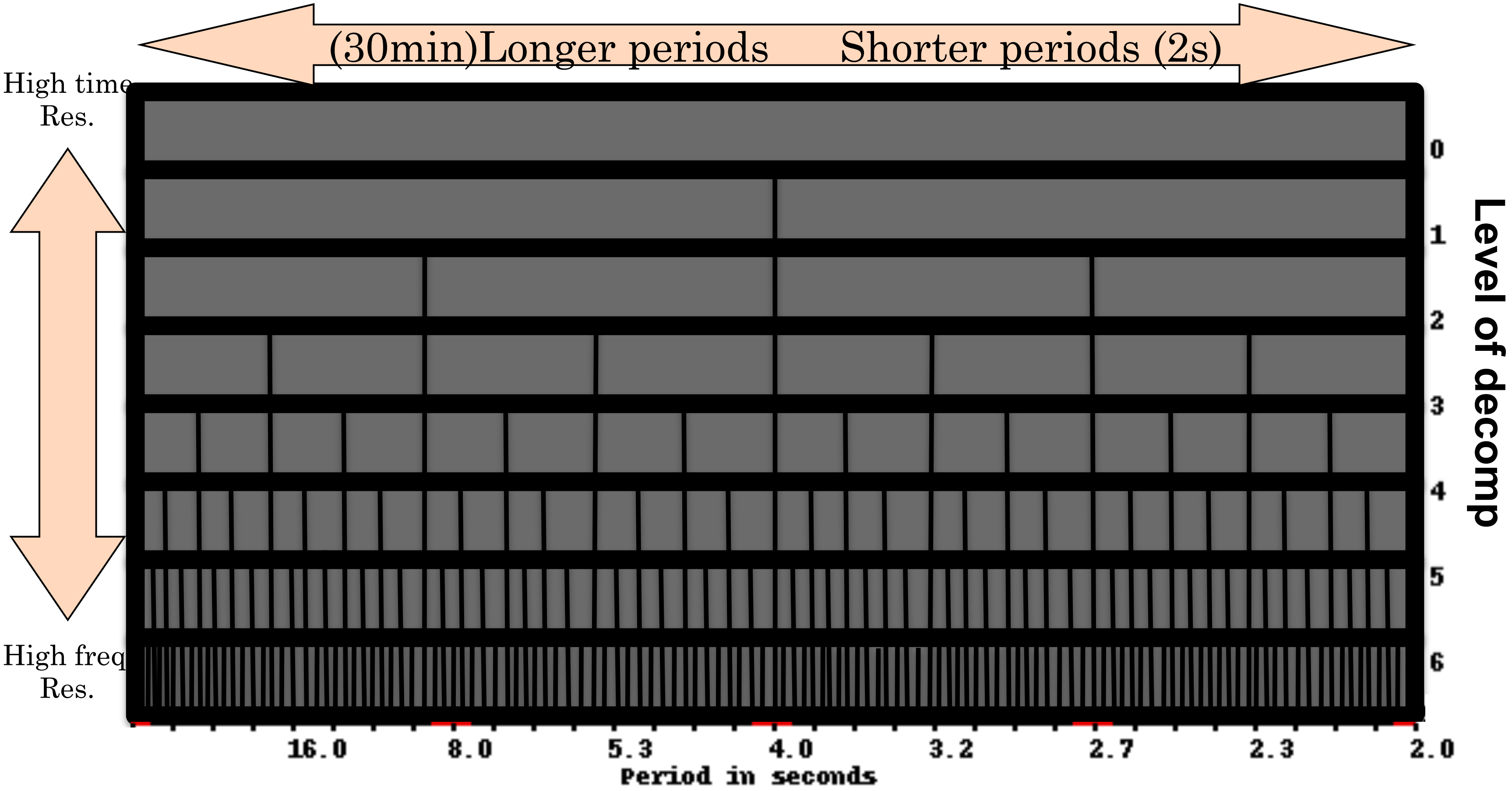

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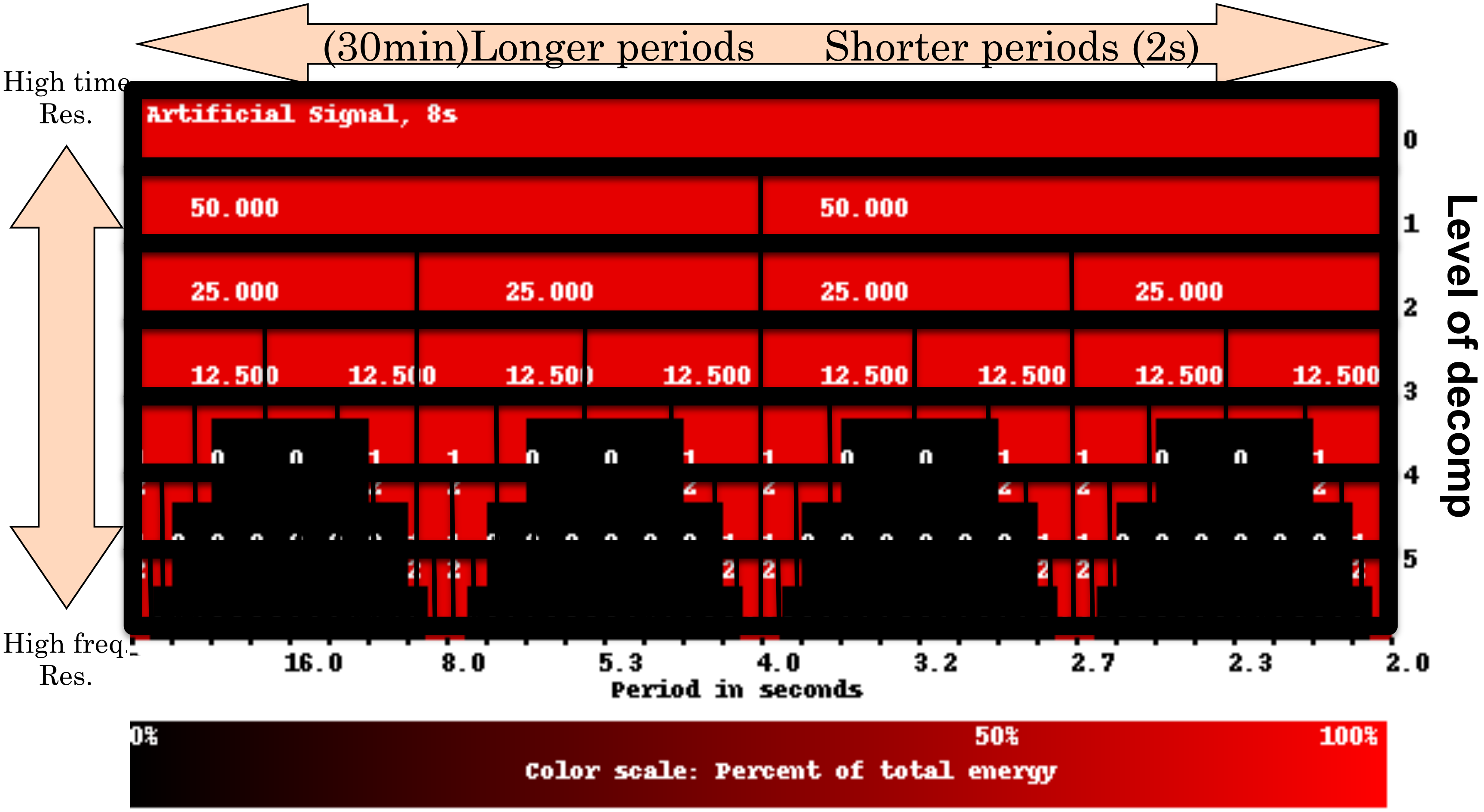

(30min)Longer periods

Shorter periods (2s)

High time Res.

High freq. Res.

Level of decomp

ARTIFICIAL EXAMPLE: 8S PERIOD

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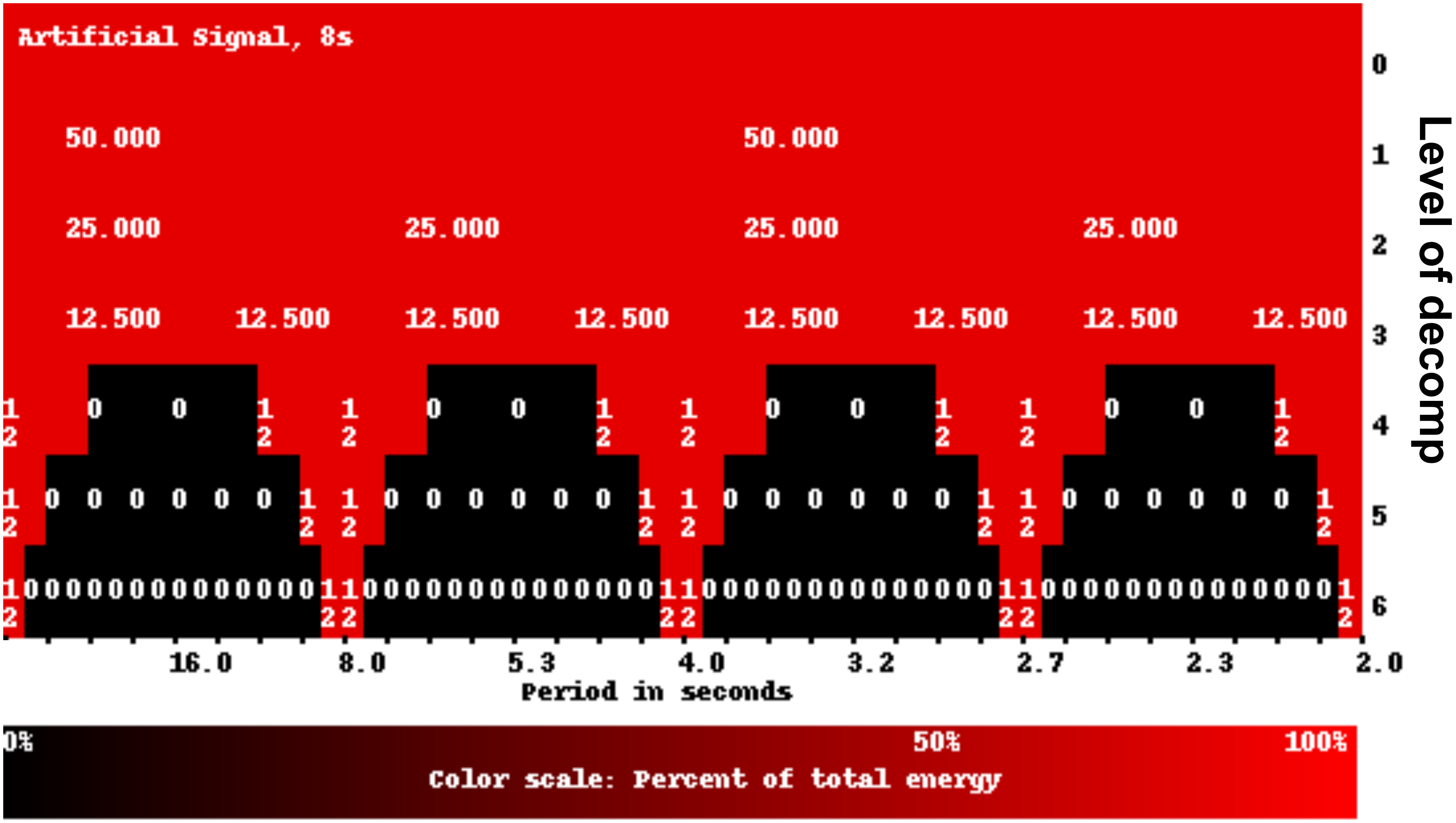
Shorter periods (2s)

High time Res.

High freq. Res.



base

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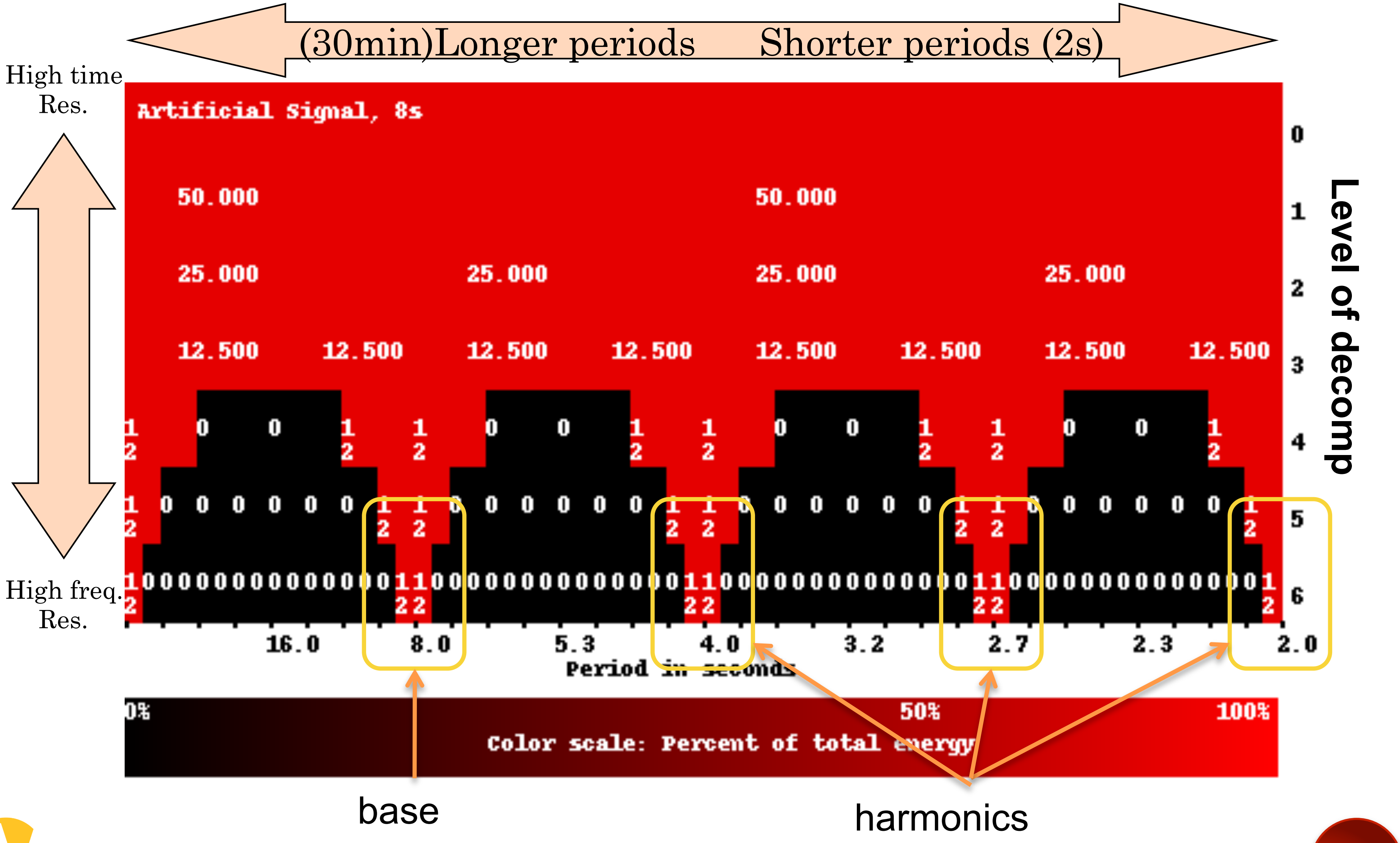
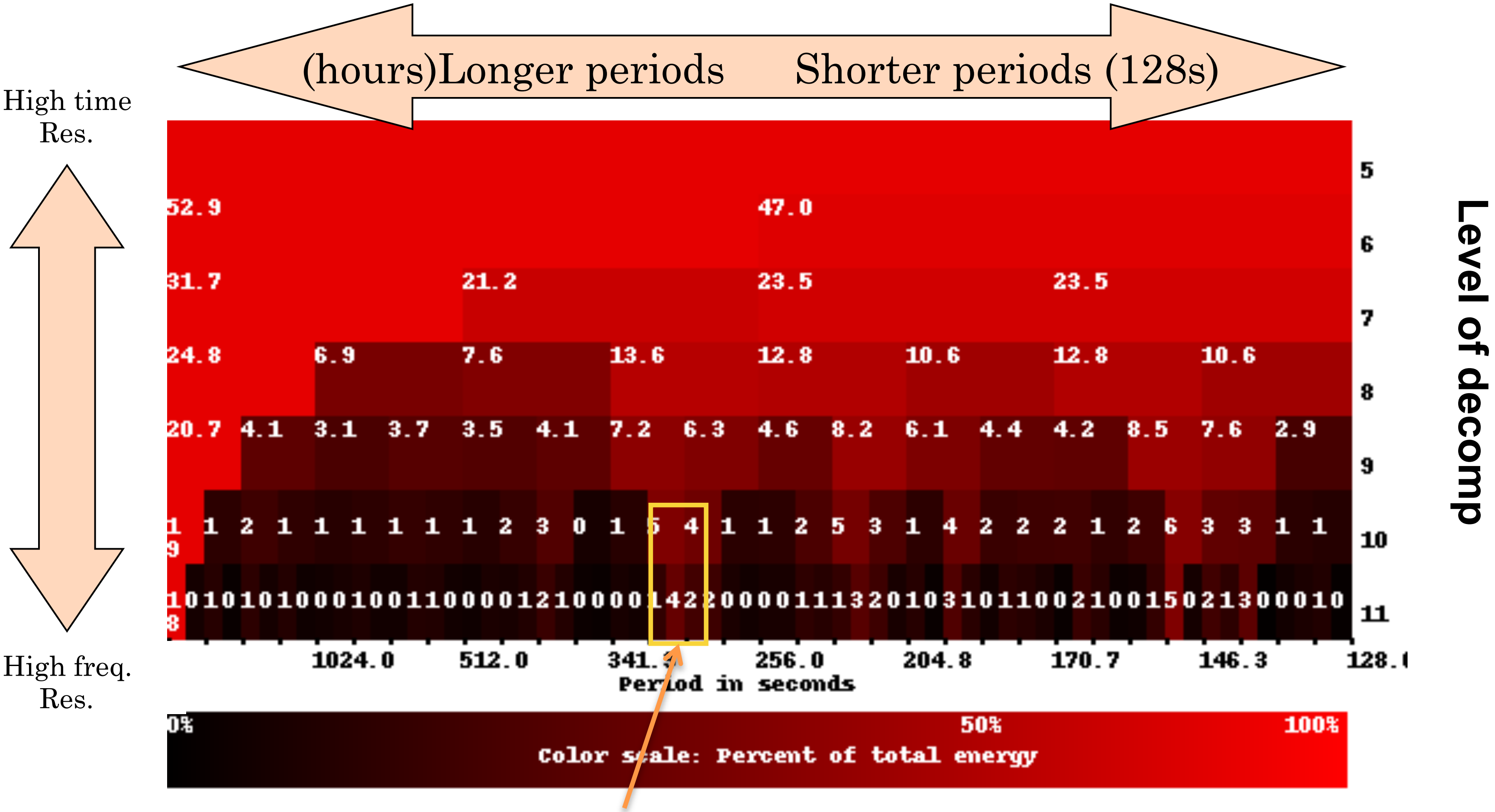


VISUALIZATION: REAL-WORLD EXAMPLE

BitTorrent client communicating with tracker



300s update with BitTorrent Tracker

AUTOMATIC DETECTION

- Detection of period
  - Empirically derived threshold on energy
  - Threshold dependent on frequency range and decomposition level
    - Too few decompositions, not focused on frequency range
    - Too many decompositions, energy spreads out
- Detection of *when* a change occurs
  - Start and stop of a periodic series of events
  - Move backwards on levels of decomposition to get more time resolution
    - Details in techreport

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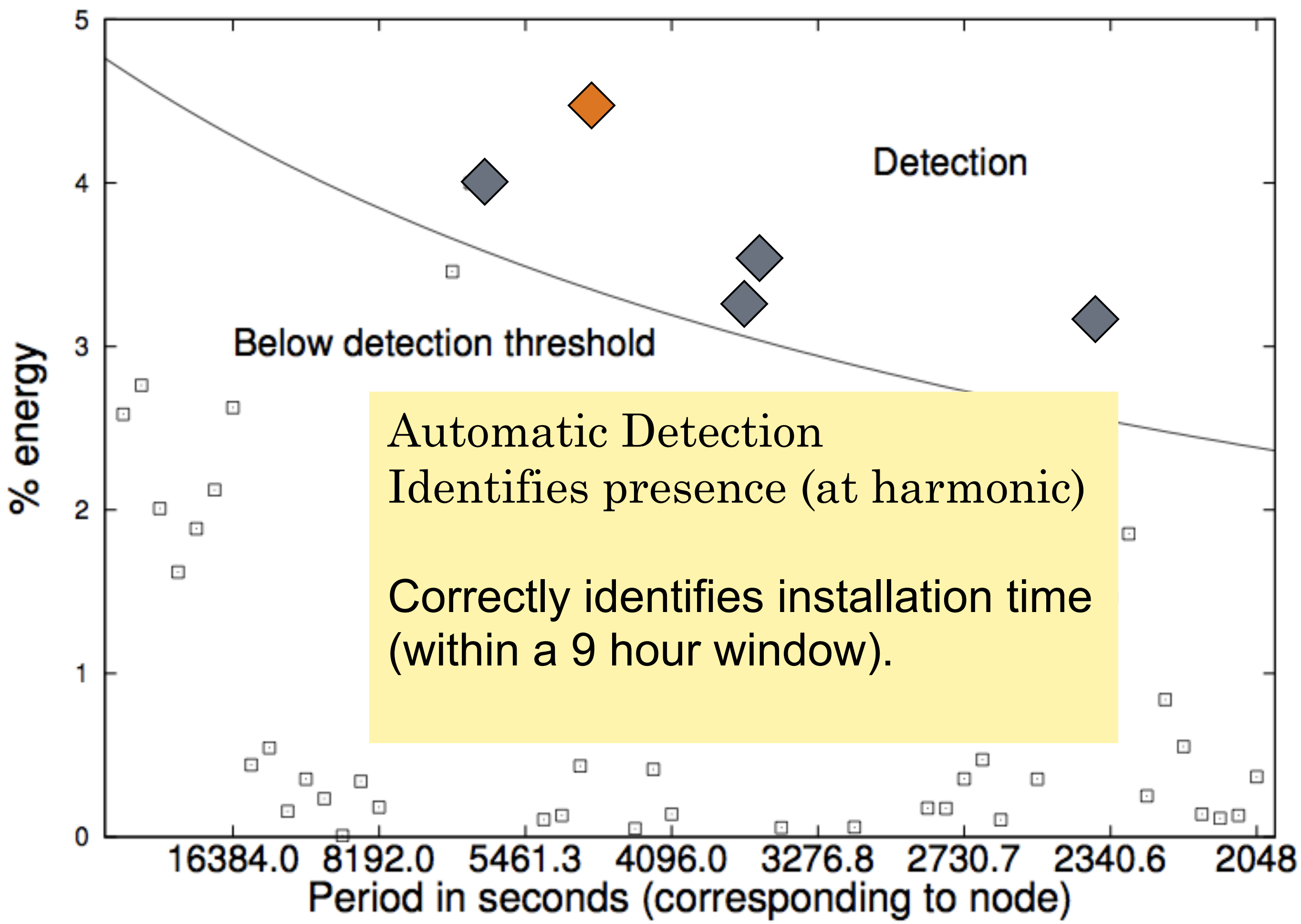
APPLICATIONS

- Self-surveillance
  - Desktop user
  - Changes indicate problems: stop in OS updates, addition of adware etc.
- Pre-filtering
  - Target apps with low-rate periodic com.
  - Reduce set of hosts to investigate
  - Eg. Target BitTorrent trackers

SELF-SURVEILLANCE DEMONSTRATION

- Detect start or stop of periodic communication
- Here we look at unwanted communication: installation of a keylogger
- Applies to stop of wanted periodic communication too!
- Detect install of Keyboard Guardian on Windows
  - Set to report every 3 hours
- 3 day monitoring
  - 1st day, no keylogger
  - 2nd day, install keylogger

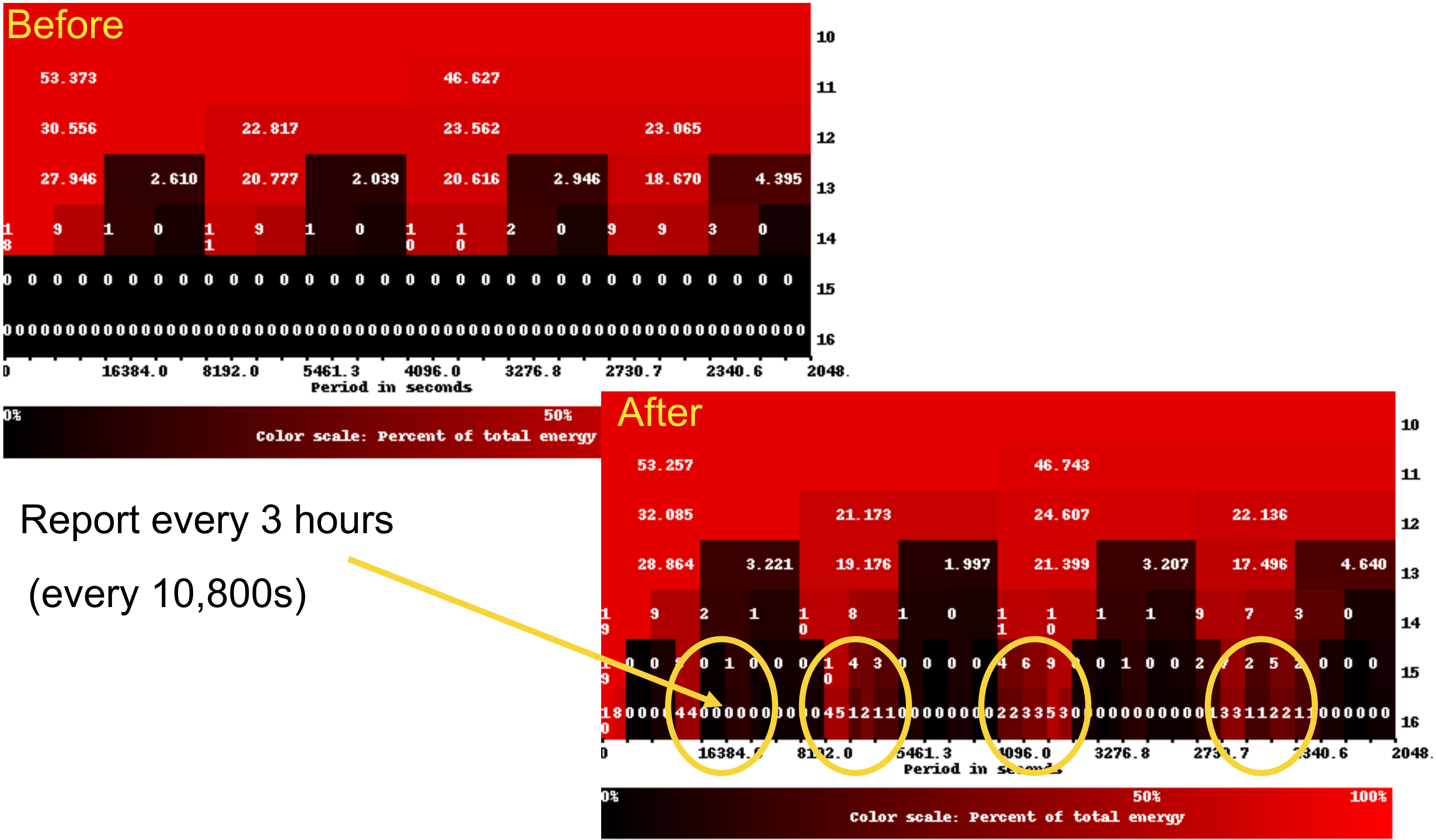
NUMERICAL DETECTION OF EVENT



Automatic Detection
Identifies presence (at harmonic)

Correctly identifies installation time (within a 9 hour window).

VISUAL DETECTION OF CHANGE



Report every 3 hours

(every 10,800s)

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SUMMARY OF SELF-SURVEILLANCE

- Automatic detection
  - Identifies a periodic series of events
  - Identifies changes in events and when those changes occur
- Demonstrated
  - Keylogger: Addition of a bad series of periodic communication
  - OS updates: Removal of a good series of periodic communication (techreport)

SENSITIVITY TO NOISE

- Signal-to-Noise ratio
  - 1 signal connection:10-20 unrelated connections
  - Easily achievable with periods of user inactivity
  - Watch for a long enough window

SUMMARY

- Variety of applications show periodic behavior
- New wavelet based approach to finding periodic behavior in aggregate traffic
- Demonstrated use for self-surveillance
- Techreport & GI paper:
  - http://www.isi.edu/~bartlett/pubs/Bartlett09a.html
  - http://www.isi.edu/~bartlett/pubs/Bartlett11a.pdf

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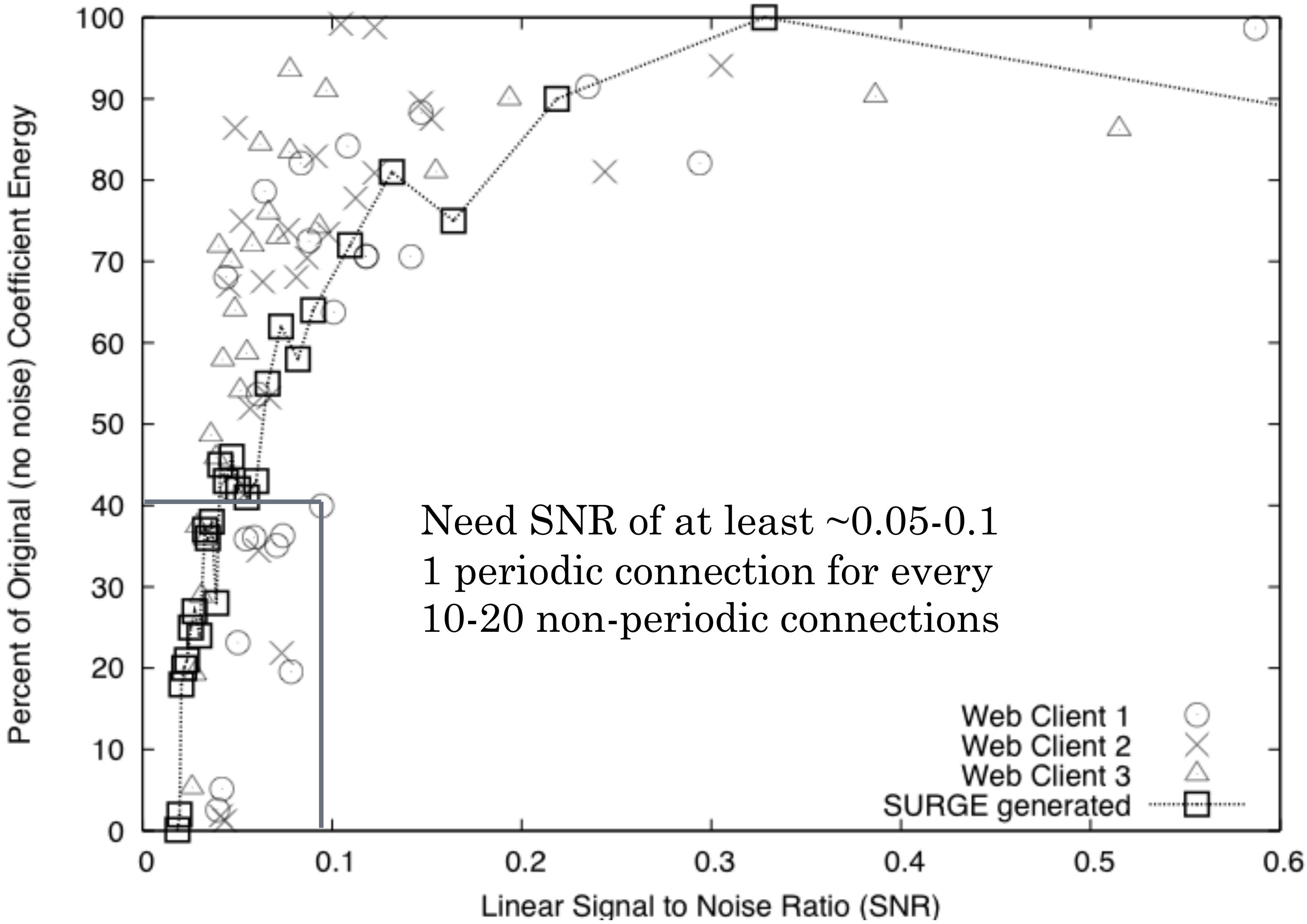
EXTRAS

HOW TO QUANTIFY SENSITIVITY?

- Why?
  - Know when we work and when we won’t
- Quantify sensitivity to noise
  - Fixed amount of background traffic
  - Vary frequency
  - Study base frequency energy
    - With background/No background

SENSITIVITY TO NOISE



Need SNR of at least ~0.05-0.1
1 periodic connection for every
10-20 non-periodic connections

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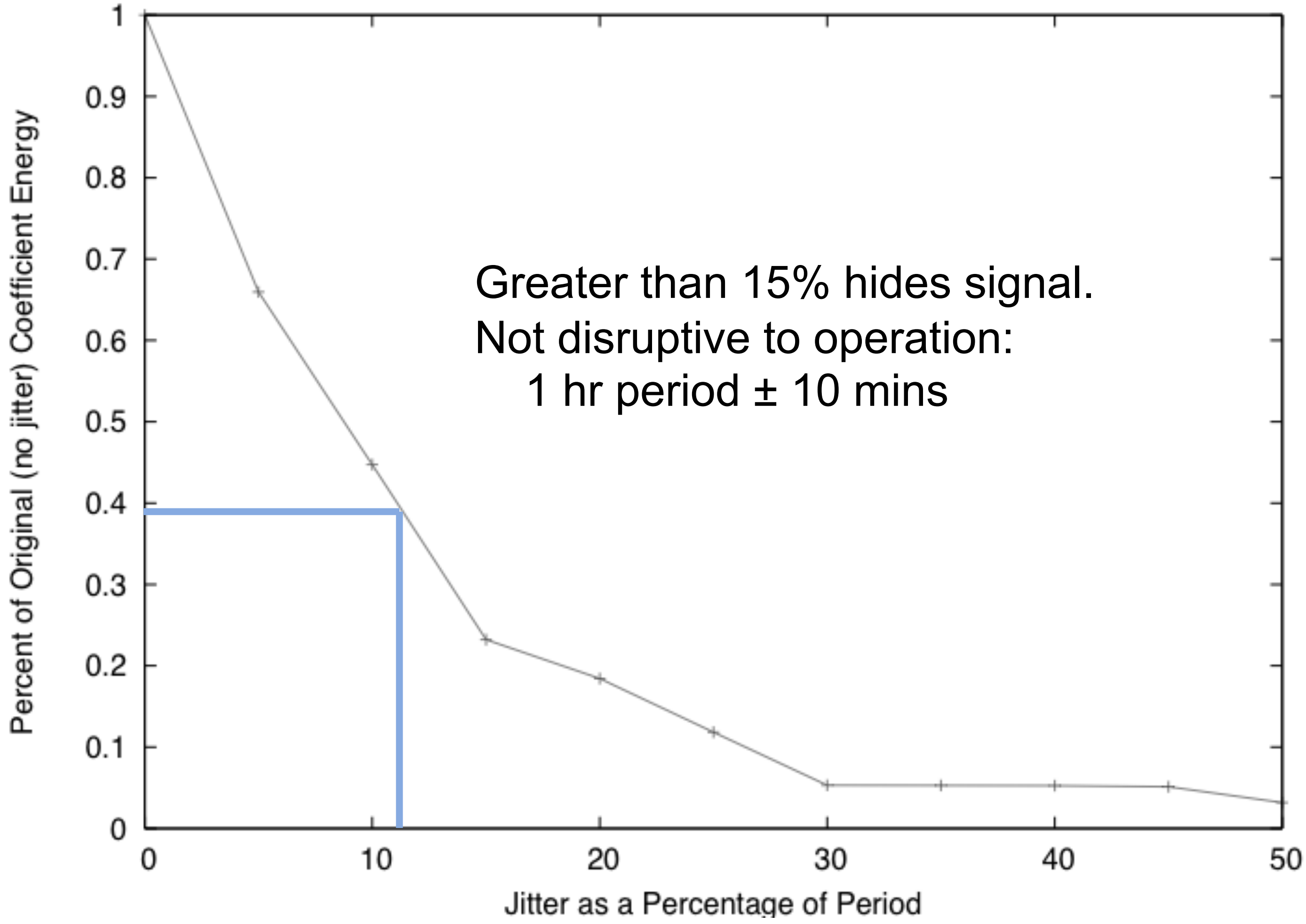
IS EVASION POSSIBLE?

- Yes: Jitter
- How much jitter is enough?
- Experiment: vary jitter, study detection
  - Artificial signal
  - Jitter varies by Gaussian random

EVALUATING JITTER FOR EVASION



Greater than 15% hides signal.
Not disruptive to operation:
1 hr period ± 10 mins