Attribution and Aggregation of Network Flows for Security Analysis

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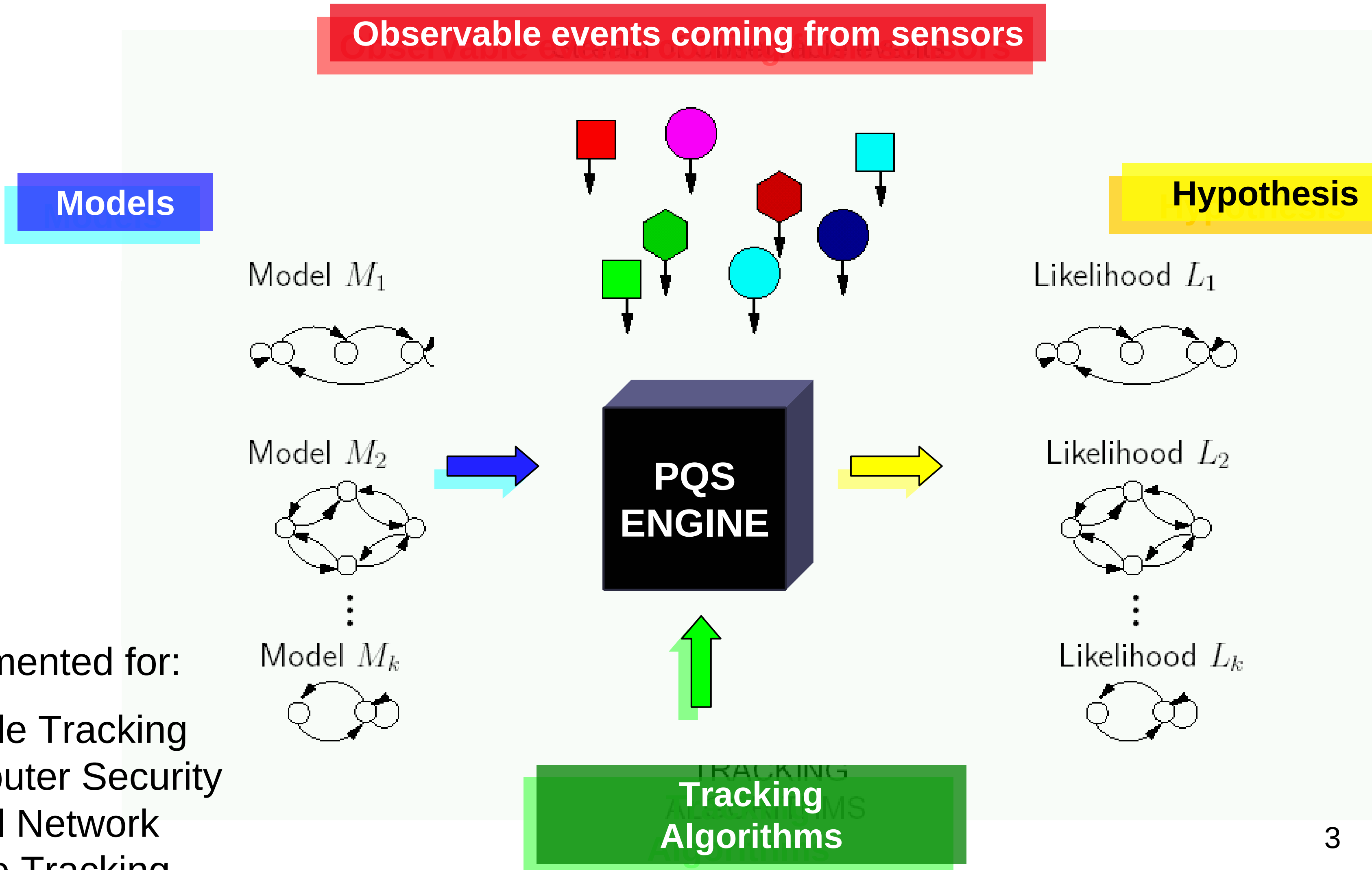
Why flow data

The context in which we are interested in flow analysis is the following.

- We believe that **automated correlation** is hard to do.
- The world consists of **processes** so our approach to correlation is process-based..
- Introduction, in 2003, of generic process-based correlation engine concept and implementation, **Process Query System** (PQS).
    - Integration of multiple existing and new sensor types and attacks models
    - Flow aggregation and correlations between flow data with security events
    - Implementation of a **PQS based process detection for Cyber Situational Awareness.**
    - **Need for flow data**.

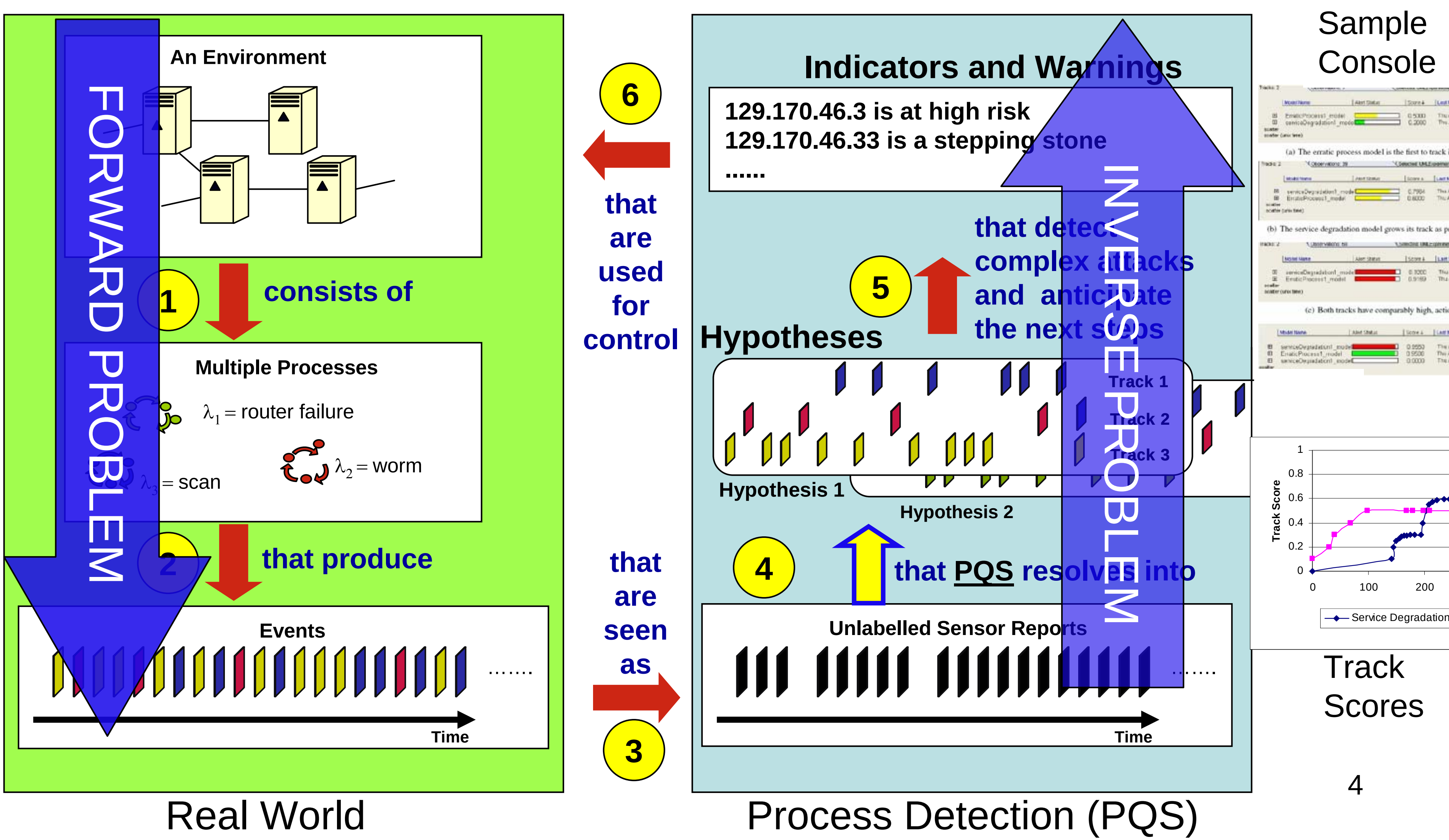
Process Query System



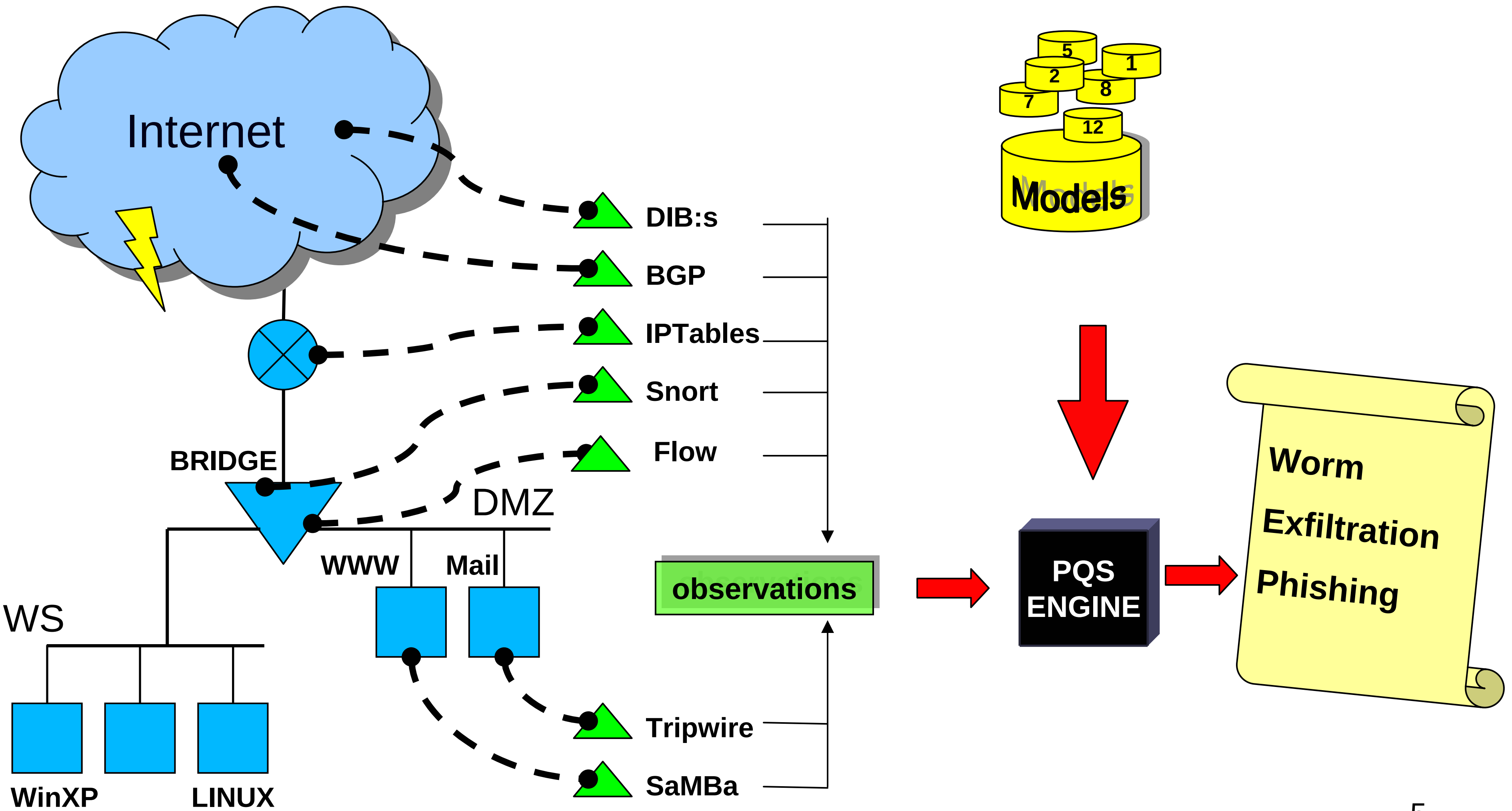
Implemented for:

- Vehicle Tracking
- Computer Security
- Social Network
- Plume Tracking

Cyber Situational Awareness



PQS in Computer Security



Sensors and Models

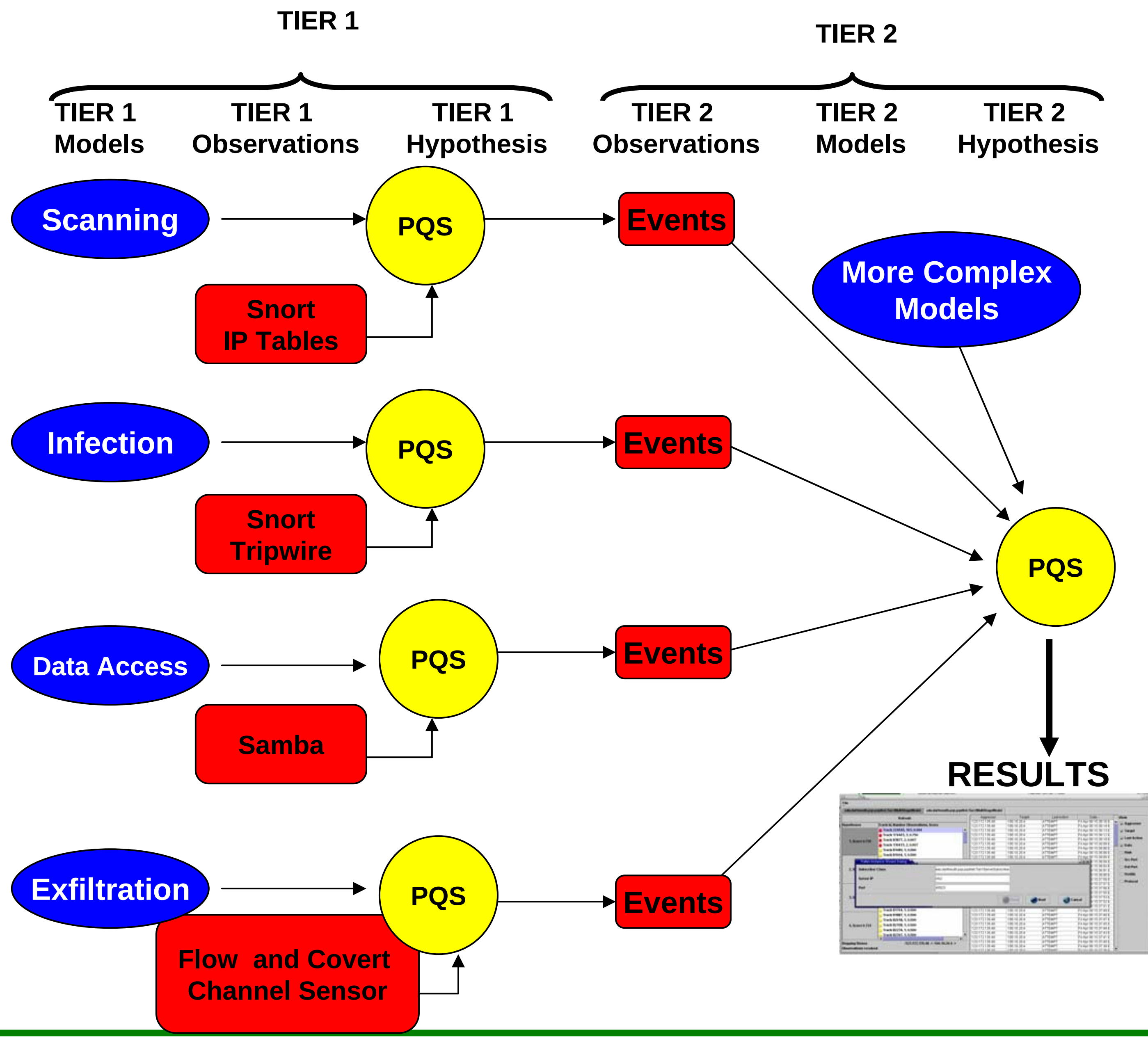
Sensors

1	DIB:s	Dartmouth ICMP-T3 Bcc: System
2	Snort, Dragon	Signature Matching IDS
3	IPtables	Linux Netfilter firewall, log based
4	Samba	SMB server - file access reporting
5	Flow sensor	Network analysis
6	ClamAV	Virus scanner
7	Tripwire	Host filesystem integrity checker

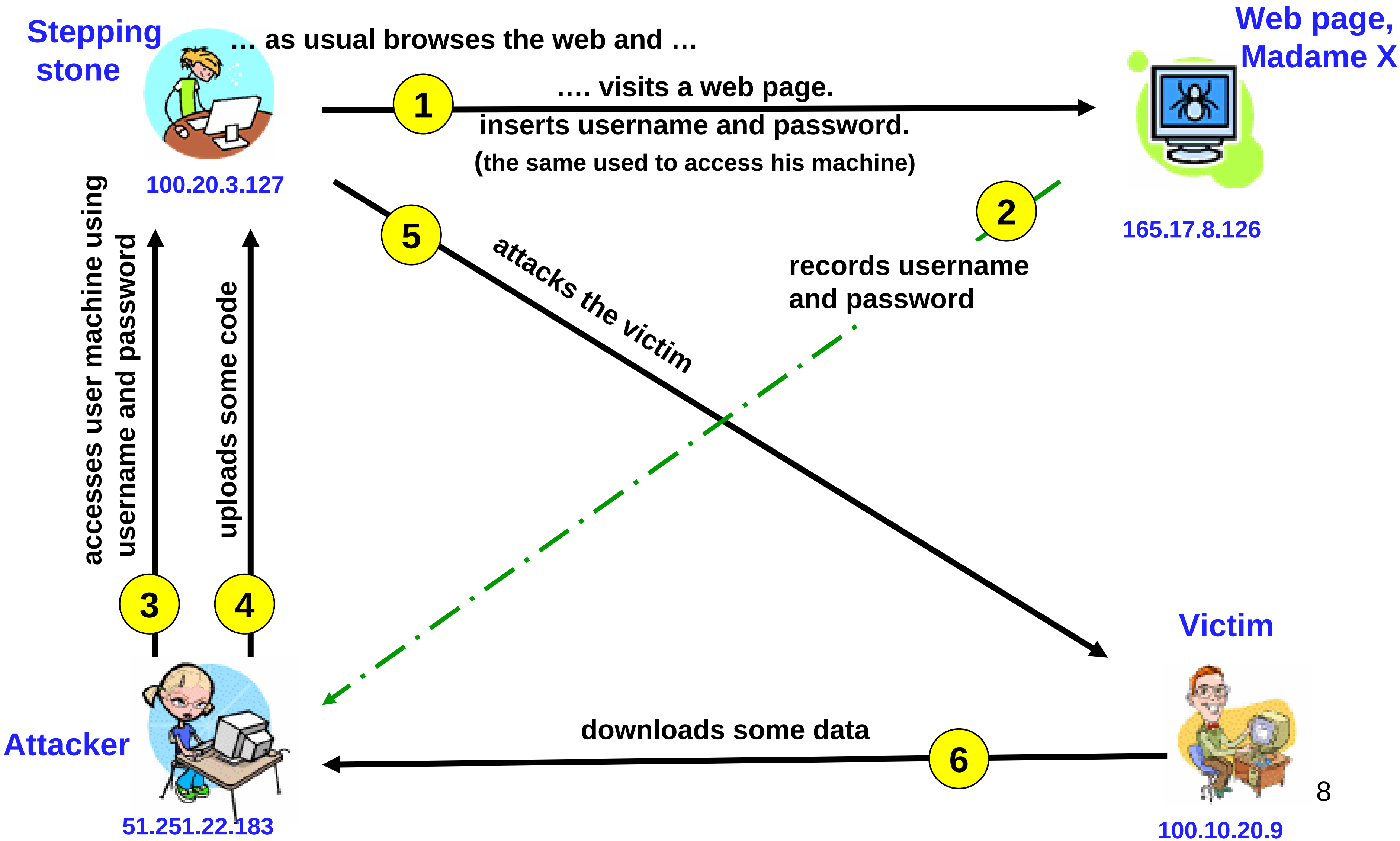
Models

1	Noisy Internet Worm Propagation – fast scanning
2	Email Virus Propagation – hosts aggressively send emails
3	Low&Slow Stealthy Scans – of our entire network
4	Unauthorized Insider Document Access – insider information theft
5	Multistage Attack – several penetrations, inside our network
6	DATA movement
7	TIER 2 models

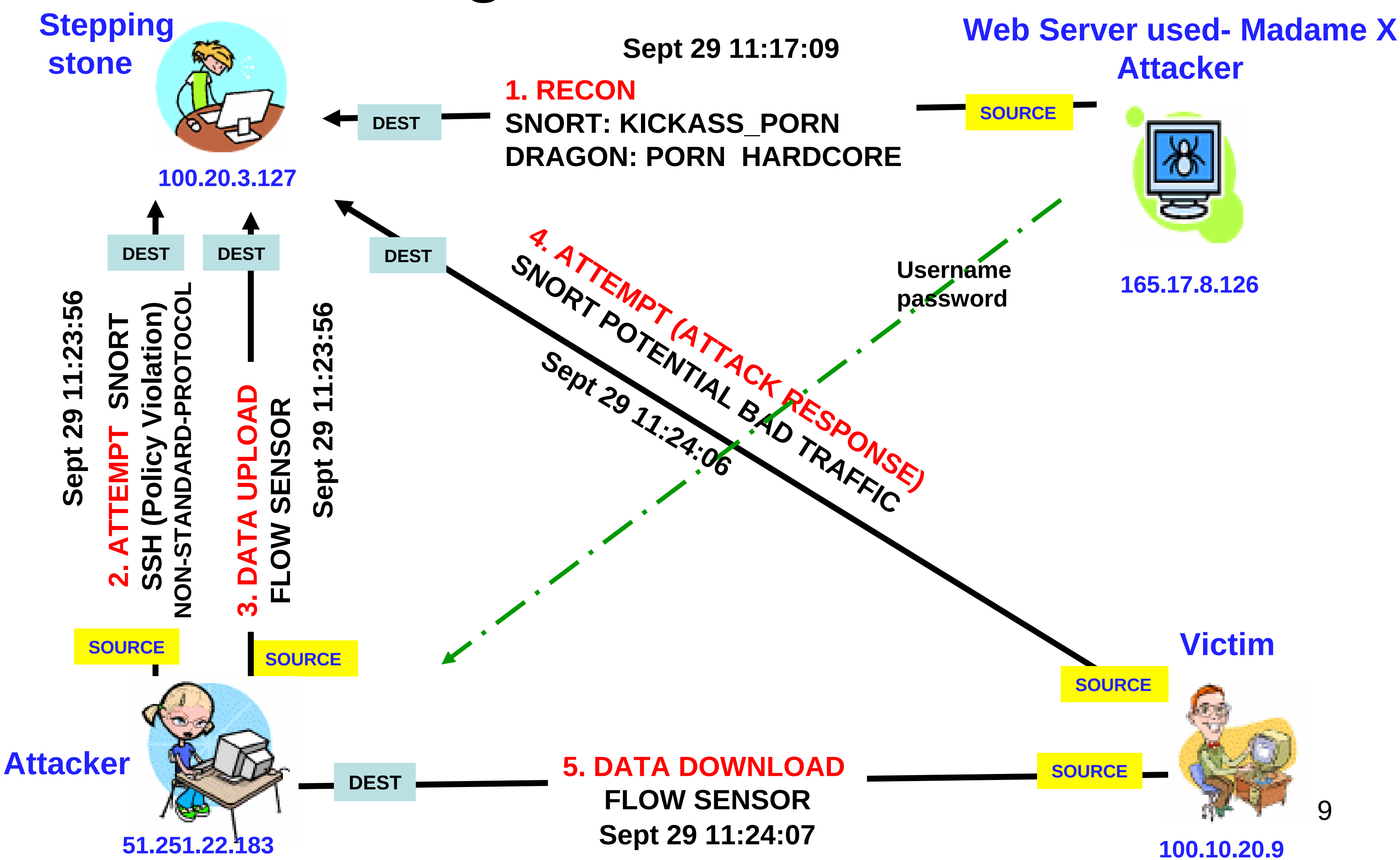
Hierarchical Architecture



Multi Stage Attack Example: Phishing



Phishing Attack Observables



Flow Sensor

Based on the *libpcap* interface for packet capturing.

Packets with the same source IP, destination IP, source port, destination port, protocol are aggregated into the same flow.

- Timestamp of the last packet
- # packets from Source to Destination
- # packets from Destination to Source
- # bytes from Source to Destination
- # bytes from Destination to Source
- Array containing delays in microseconds between packets in the flow

PQS Process Query Systems

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Two Models Based on the Flow Sensor

Low and Slow UPLOAD

Volume	Packets	Duration	Balance	Percentage
Tiny: 1-128b Small: 128b-1Kb	4:10-99 5: 100-999 6: > 1000	4: 1000-10000 s 5: 10000-100000 s 6: > 100000 s	Out	>80

UPLOAD

Volume	Packets	Duration	Balance	Percentage
Tiny: 1-128b Small: 128b-1Kb Medium: 1Kb-100Kb Large: > 100Kb	1: one packet 2: two pckts 3: 3-9 4: 10-99 5: 100-999 6: > 1000	0: < 1 s 1: 1-10 s 2: 10-100 s 3: 100-1000 s 4: 1000-10000 s 5: 10000-100000 s 6: > 100000 s	Out	>80

Aggregation

Flow aggregation.

Recognizing that different flows, apparently totally unrelated, nevertheless belong to the same broader event (activity).

Flows are aggregated from captured network packets.

We aggregate flows into **activities**.

Example:

User requests a webpage (all DNS and HTTP flows aggregated)

Activity aggregation.

Recognizing that similar activities occur regularly at the same time, or dissimilar activities occur regularly in the same sequence.

We correlate activities into **activity groups, patterns**.

Examples:

- Nightly backups to all servers (each backup is an activity)
- User requests a sequence of web-pages every morning.

Packet = Aggregated Bytes
Flow = Correlated Packets
Activity = Correlated Flows
Pattern = Correlated Activities

Web Surfing in Detail

1. The **browser communicates with a name server** to translate the server name "www.dartmouth.edu" into an IP Address, which it uses to connect to the server machine.

   A FLOW IS INITIATED

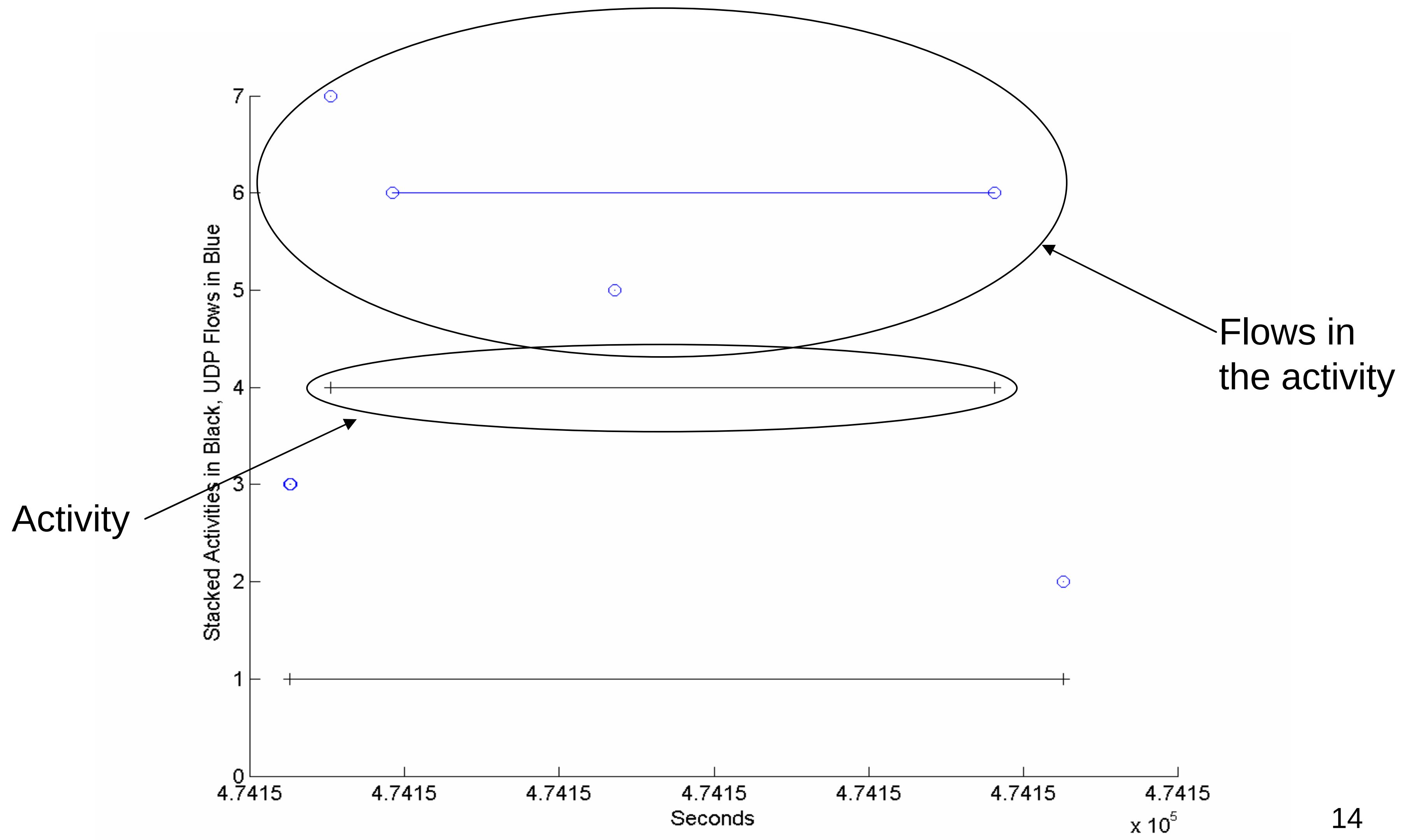
2. The **browser forms a connection to the web server** at that IP address on port 80.

   A FLOW IS INITIATED

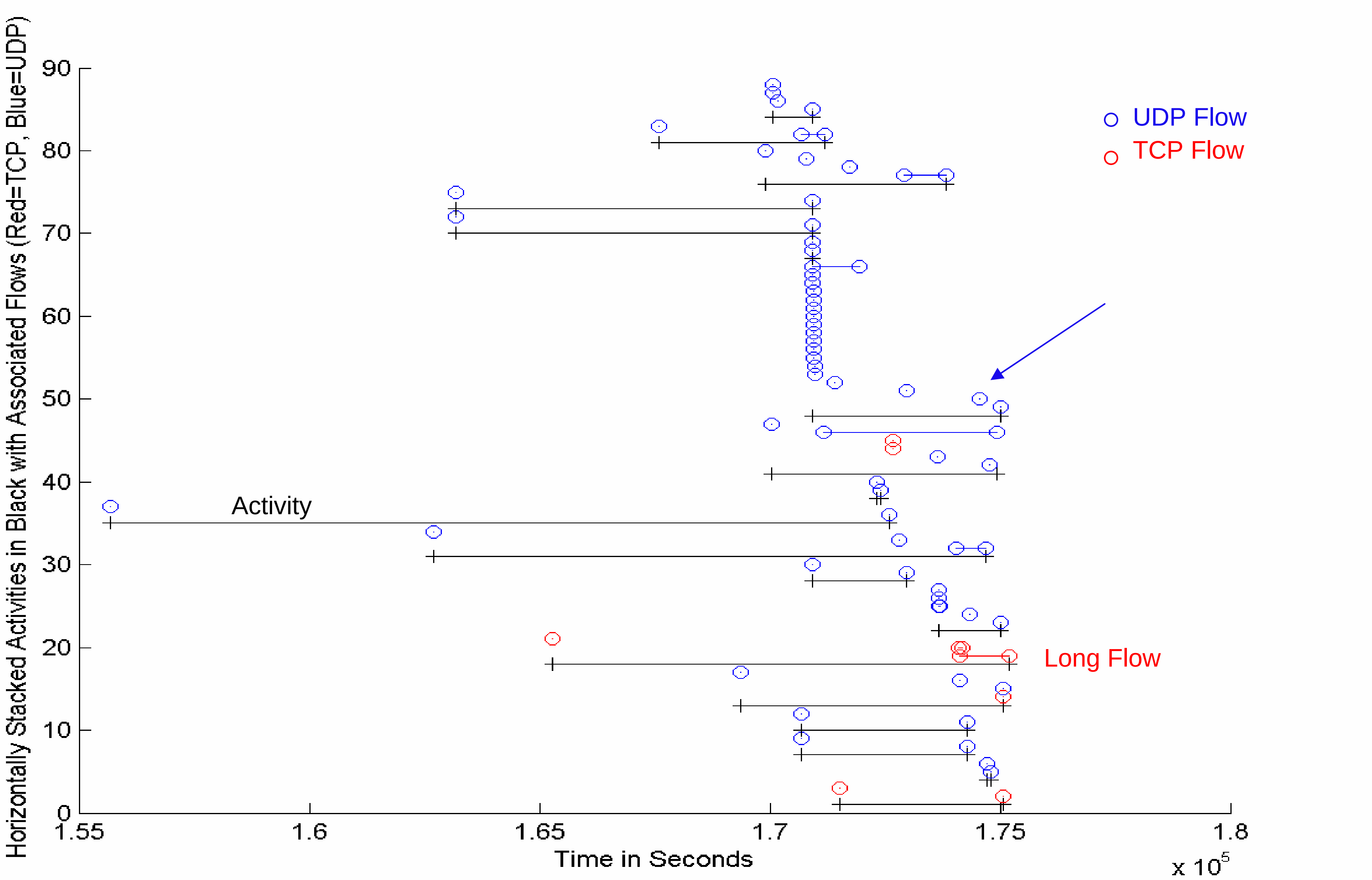
3. Following the HTTP protocol, the browser sends a GET request to the server, asking for the file "http://www.dartmouth.edu/index.html."
4. The web server sends the HTML text for the Web page to the browser.
5. The browser reads the HTML tags and formatted the page onto your screen.
6. Browser possibly initiates more **DNS requests for media** such as images and video.
7. Browser initiates more **HTTP and/or FTP requests for media.**

MULTIPLE FLOWS ARE INITIATED…

Resulting Flows and Activity

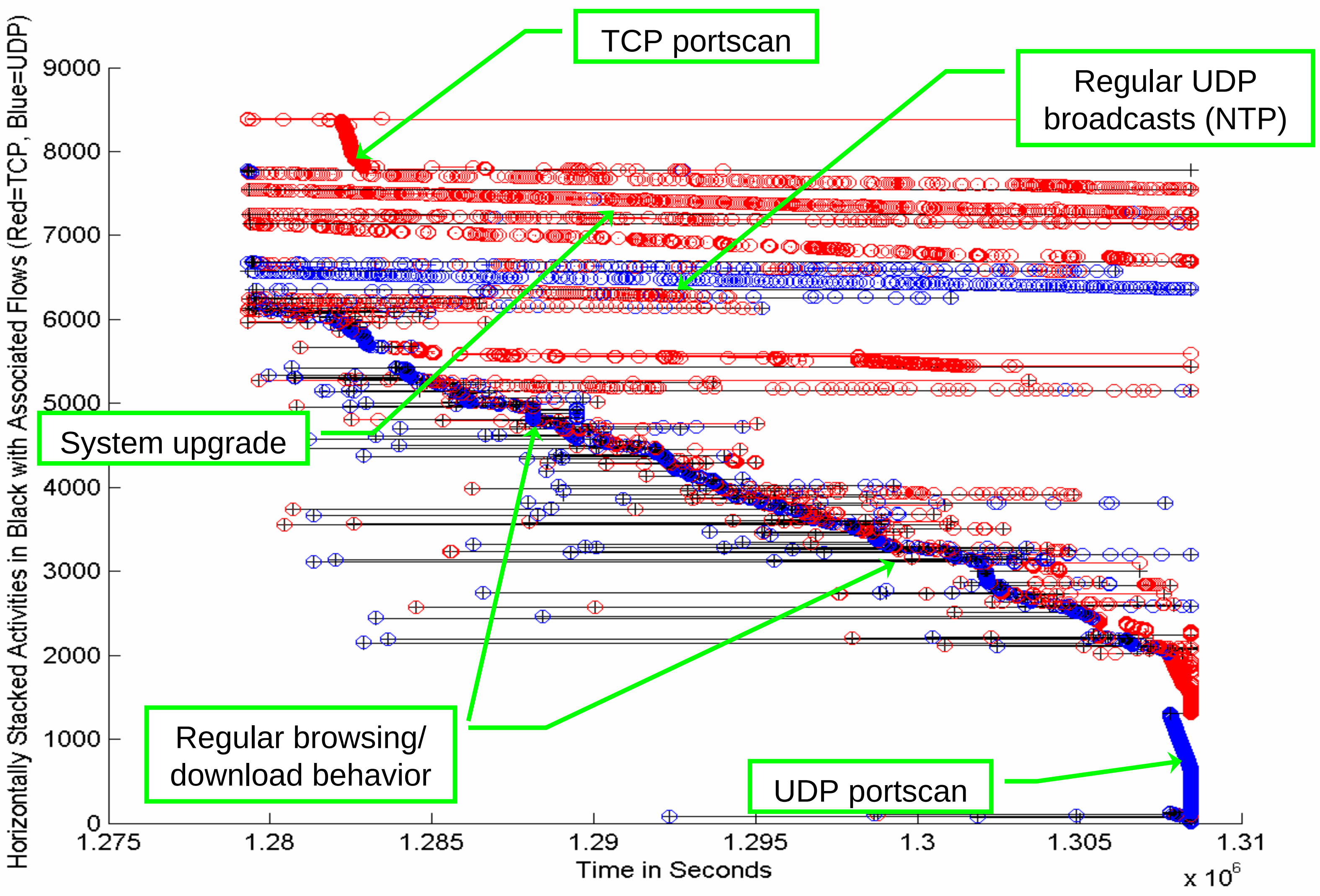


Activities and Flows



Complex Activities ....

Correlated Network Flows Within a LAN



PQS Process Query Systems

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Packets in a flow triggered IDS alerts

PQS instantiates models based on observation coming from flow and snort sensor.

Snort rule **1560** generates an alert when an attempt is made to exploit a known vulnerability in a web server or a web application.

Snort rule **1852** generates an alert when an attempt is made to access the 'robots.txt' file directly.

Timestamp	Sensor	src IP	dst IP	Proto
Jul 09 16:28:32	S1852	65.54.188.140	208.253.154.195	TCP
Jul 09 16:29:35	S1852	65.54.188.140	208.253.154.195	TCP
Jul 09 16:44:44	S1560	65.54.188.140	208.253.154.195	TCP
Jul 09 18:26:08	S1560	65.54.188.140	208.253.154.195	TCP
Jul 09 21:05:03	S1852	65.54.188.140	208.253.154.195	TCP
Jul 09 22:31:08	S1852	65.54.188.140	208.253.154.195	TCP
Jul 09 22:31:08	S1560	65.54.188.140	208.253.154.195	TCP
Jul 10 02:45:19	S1852	65.54.188.140	208.253.154.195	TCP
Jul 10 02:45:23	S1852	65.54.188.140	208.253.154.195	TCP
Jul 10 09:21:15	S1852	65.54.188.140	208.253.154.195	TCP
Jul 10 14:33:43	S1852	65.54.188.140	208.253.154.195	TCP
Jul 10 17:54:54	S1852	65.54.188.140	208.253.154.195	TCP
Jul 10 22:07:02	S1852	65.54.188.140	208.253.154.195	TCP
Jul 11 01:38:09	S1852	65.54.188.140	208.253.154.195	TCP
Jul 11 04:05:54	S1852	65.54.188.140	208.253.154.195	TCP
Jul 11 04:20:00	S1852	65.54.188.140	208.253.154.195	TCP
Jul 11 04:20:00	S1852	65.54.188.140	208.253.154.195	TCP
Jul 11 11:07:12	S1852	65.54.188.140	208.253.154.195	TCP
Jul 11 11:56:12	S1852	65.54.188.140	208.253.154.195	TCP
Jul 11 17:16:59	S1852	65.54.188.140	208.253.154.195	TCP
S Jul 10 02:30:27 E Jul 10 23:55:56	F	65.54.188.140	208.253.154.195	TCP

SNORT ALERTS

FLOW

Table 2: A sample track of correlated IDS and Flow events

The flow can be characterized as malicious and further investigation must be done.

Future Direction

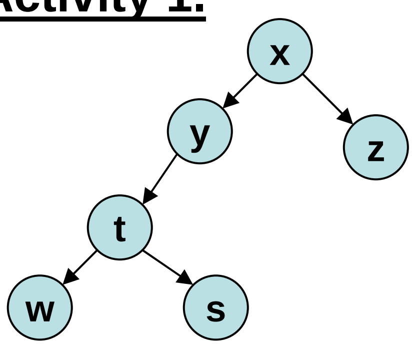
Theoretical approach for clustering aggregated flows.

Flow = As defined
Activity = Aggregated flows
Pattern = Correlated Activities

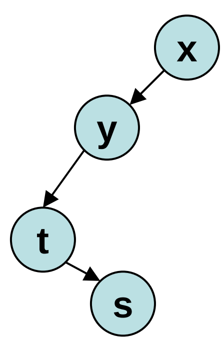
Approach: Graph theory (flows are the nodes and the edges are between correlated nodes).

We are thinking about defining a metric that captures the closeness between two different activities to allow grouping into patterns.

Activity 1.



Activity 2.



Can they be grouped in one pattern?
Notion of distance between activities.

www.pqsnet.net

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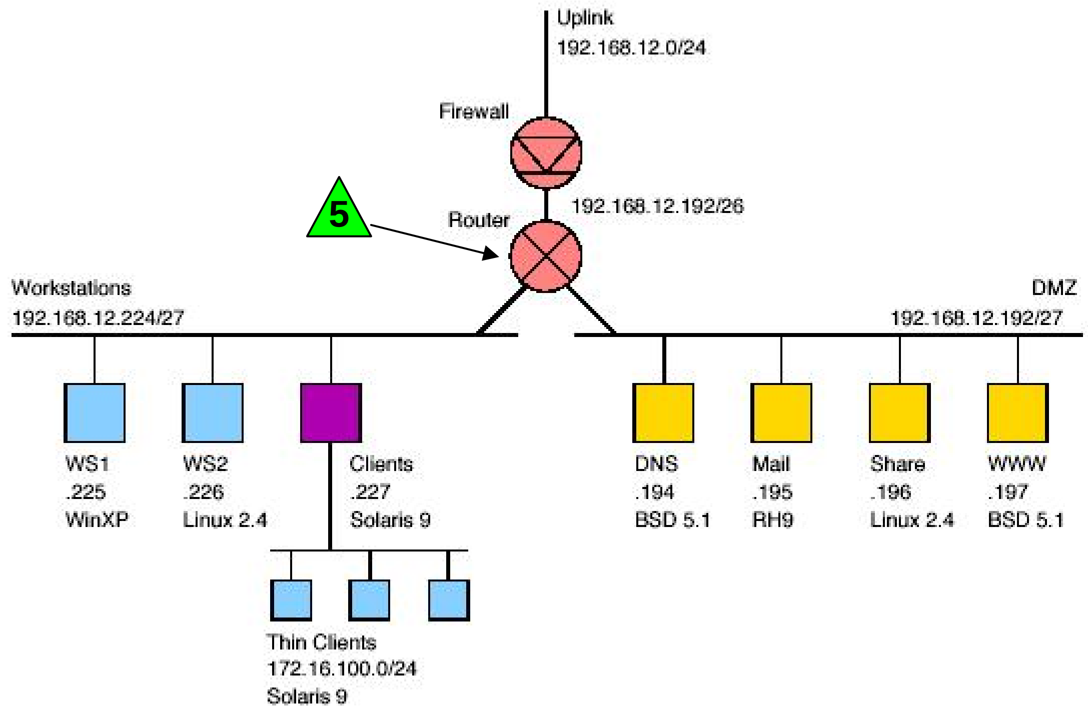
PQS-Net Network



Student and researcher use this network to browse the web, print documents, send upload and download files…

PQS Process Query Systems

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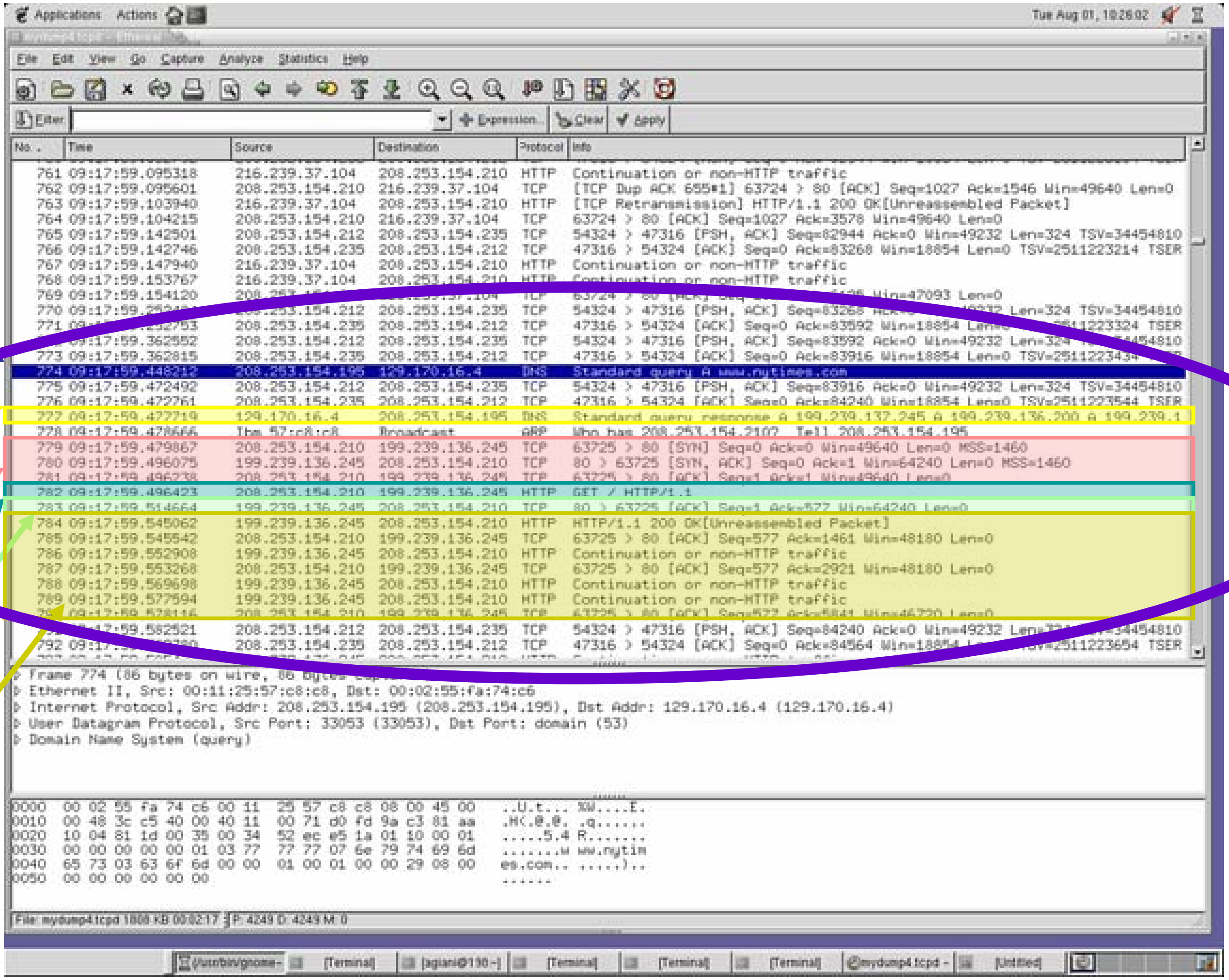
Web Surfing

208.253.154.210	**host name**
208.253.154.195	**dns.pqsnet.net**
129.170.16.4	**ns.dartmouth.edu**

1. **ns.pqsnet.net requests www.nytimes.com ip address to ns.dartmouth.edu**
2. **ns.dartmouth.edu returns the ip address – 199.239.136.245**
3. **TCP three-way handshake between the host machine and the web server.**
4. **HTTP GET request to 199.239.136.245**
5. **TCP ACK from the web server**
6. **Other packets exchanges between the web server and the host**



All these network connections are related to the same host activity.