Implementing Packet Dynamic Awareness in Argus

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FloCon 2012
Austin, Texas
Jan 10, 2012
New ideas are needed to improve computer network defense with regard to scalable attack attribution (AA) and situational understanding (SU).

Packet Dynamics are a new set of flow-level variables, including, but not limited to, inter-packet arrival, protocol state transition, one-way and round trip latency, transaction duration and session arrival times.

Packet Dynamic metrics can provide new additional awareness needed to deliver flow based anomaly detection for a number of difficult issues.

We will discuss its implementation in Argus, and how we use Packet Dynamics in near-realtime cyber-situational awareness systems.
Packet Dynamics

- Dynamics generally refer to property change over time.

- Packet dynamics (PD) have been described as connection-level properties such as packet shaping, ordering, loss and delay, and how they change over time.


- Packet dynamics include many properties such as inter-packet arrival times, packet burst behavior, protocol state transition times, latency, and packet size frequency.

- New understanding of packet dynamics can provide additional awareness needed for successful network path assurance, man-in-the-middle detection, stepping stone detection, replay and attribution.
Packet Dynamics

- Replay attack detection
  - Bi-Directional Protocol Time Uncoupling
- Stepping stone detection
  - Two completely independent flows, that share the same instantaneous burst behavior and packet size frequency distribution (shifted for encapsulations)
- Man vs Machine detection
  - Interactive vs Non-Interactive Session Detection
  - Packet, transaction and session jitter analysis
- Man-in-the-middle detection
  - Pass Thru - Detectable one-way latency, hop count, path resource modifications
  - Proxy - Connection setup time modifications, header attribute changes
- Performance as an Asset that needs Protection
  - Path Availability, Bandwidth, Latency, Jitter, MTU, ....
  - Continuous One-Way latency determinations
TCP Replay Attacks

• Predicting a machine’s next TCP base sequence number enables elementary trusted source attacks.
  
  • Attack a remote target, such as a border router, by simply streaming a handcrafted TCP connection to the target machine, masquerading as an internal trusted source.
  
  • Don’t have to be in the data streams path (blind transmission).
  
  • Very common and successful strategy against older TCP/IP stacks.
  
  • Detection is very difficult with simple uni-directional flow data.

• Awareness of the packet dynamics of the attacking TCP connection can lead to simple and immediate detection.
TCP Normal Connection

- State Development Time
  - TCP Setup Time
  - Data Presentation Delay
  - Data Transport Time
  - TCP Teardown Time

- Host Dynamics
  - Data Burst Rate
  - Data Ack Delay
  - Host Processing Time

- Network Dynamics
  - One-way Delay (shaping)
  - Round Trip Time
  - Loss Rate
TCP Replay

Sender

- Attacker generally sends entire TCP connection all at once.
  Sophisticated attempts inject pseudo packet delay

- State dynamics ignored
  RTT Insensitive
  TCP Setup Time
  Data Transport Time
  TCP Teardown Time
TCP Replay Receiver

- Receiver responds in a conventional manner

Dynamics, however, shifted toward being driven by processing delay, rather than network delay.
TCP Replay Connection

- Overall connection is contracted
  All data transport appears to be at line rate

- Protocol state violated
  Response seen before Request
  ACKs before Data
  Impossible TCP Setup Time
  Packets out of phase but not out of order
  Massive TCP Teardown Time
Argus Based Packet Dynamics

- Bi-Directional Protocol State Monitoring
  - Protocol State Tracking / Durations
    - TCP connection setup duration
      - SYN -> SYN_ACK and SYN_ACK -> ACK time
    - TCP connection teardown duration
      - FIN -> FIN_ACK and/or FIN -> RESET time
    - TCP state transition reporting
  - Transport performance
    - RTP / TCP / UDT loss reporting
    - TCP window load with size advertisements (tcpmax)

- Bi-Directional inter-packet arrival times
  - Mean, max, min, variance, frequency distribution

- Request / Response Duration Times

- Packet Size / State Correlations
SSH Keystroke Detection

- Discriminating between interactive and non-interactive network activity
- Threat model is different between automation and human interactive sessions
- Discovering SSH keystroke traffic behavior in arbitrary packet streams (UDP, IP, ICMP, ethernet) provides reliable detection
- Discerning behavior without regard to contents provides suitable continuous monitoring strategy
Algorithm Goals

- Detect SSH client keystroke packets in arbitrary traffic connections (TCP as candidate test protocol).
- Detect SSH flows in any connection, on any port.
- No packet content inspection, header only (privacy)
- Deployable in production networks at traditional observation points (performance)
- Suitable for near realtime detection and reporting (alarm / alerting)
Algorithm Strategy

1. Identify human typing patterns in offered stream
2. Track candidate single and small clustered character transmissions
3. Detect character echo as strong correlate
4. Exploit TCP protocol characteristics
5. Exploit SSH protocol specific properties
Algorithm Development

• Exhaustive statistical analysis of commodity and scripted packet traces
  • Traces from Univ. of Leipzig and Purdue Univ.
  • Represented large session variability
    • Logon failure, single command, subsystem requests

• Initial exploratory, unstructured study
  • Based on visualizations and numeric methods
    • Focus on arrival times, packet sizes, flags, seq numbers

• Followed by formal statistical testing
  • Multi-response fractional-factorial statistical experiment
Algorithm Details

SSH Protocol Rules
1. SSH Startup Handshake Detection (22 pkts)
2. SSH Packet Size (mod 4 = 0)

Packet Dynamic Rules
1. Minimum client data size (48 bytes)
2. Maximum client data size (128 bytes)
3. Maximum server echo gap size (3 pkts)
4. Minimum server echo data size (24 bytes)
5. Maximum server echo data size (256 bytes)
6. Minimum client inter-arrival time (50 mSec)
7. Maximum absolute log inter-arrival ratio (1.122)
8. Maximum previous-current gap (3 pkts)
SSH Keystroke Detection

- All data packets of the correct size ($\% 4 = 0$)
- SSH protocol in data transfer state (> 22 pkts)
- Previous packet arrival within tolerances (human typing).
- Bi-directional sequential data packet sizes within tolerances
- Data and Echo Packets RTT within tolerances
Reporting Metrics

- Argus Behavioral DSR
  - Algorithm Family Identifier (DSR subtype 8 bits)
  - Algorithm Identifier (DSR qualifier 8 bits)
  - Algorithm Specific Metrics (< 32K bytes)

- Presence of the DSR indicates that the algorithm was applied to the flow during the status interval.

- Presence of algorithm metrics indicate that there were analytic results during the status interval.

- Algorithm generates keystroke counts for both directions.

- DSR meets all Argus DSR operational requirements
  - ra keyword “nstroke” (number of keystrokes)
  - printable, graphable, filterable, aggregatable, etc.....
Model of Situational Awareness in Dynamic Decision Making

Network Flow Data Usage

Task/System Factors

- State of the Environment

Individual Factors

- Goals & Objectives
- Preconceptions (Expectations)

Situational Awareness

- Perception of Elements in Current Situation
  - Level 1
- Comprehension of Current Situation
  - Level 2
- Projection of Future Status
  - Level 3

Feedback

Decision

Performance of Actions

- System Capability
- Interface Design
- Stress & Workload
- Complexity
- Automation

Information Processing Mechanisms

- Long-Term Memory Stores
- Automaticity

- Abilities
- Experience
- Training

Endsley, M. R., Human Factors, Vol. 37, No. 1, 1993. Copyright 1993 by the Human Factors and Ergonomics Society. All rights reserved.
Alarming Conditions

- Keystrokes are expected in most ssh connections
- For many SSH connections the absence of keystrokes is the actionable condition
- Keystrokes should appear in various phases of an SSH.
  - Human initiated connections should have keystrokes at the beginning and end of an SSH connection.
  - Absence of keystrokes at closure, may indicate timeout conditions.
- Historical behavioral baselining will identify connections where keystroke monitoring is helpful
- Almost always (> 99.9%), the originator of the SSH connection will be doing the typing
- Anytime the destination originates keystrokes, you probably have a really serious problem !!!!!
Live Demonstration
from Presentation Laptop
ra and ratop screens with me ssh’ing to the qosient.com
hopefully we can have that going on a separate projector during the talk. need to tune the parameters for end system sensing.
Supporting Slides
Classification Variables

- Whether a packet is from the client or server
- Whether there are more than 22 packets in the connection
- Whether there are client packets after packet 22 or not
- Data size for client packets
- Data size for server packets
- The number of packets between a client packet with data and the next acknowledging server packet with data
- Inter-arrival time of two successive client packets with data
- Inter-arrival time of two successive echoing server packets
- The ratio of a client inter-arrival time and the inter-arrival time of the corresponding echoing server packets
- The number of packets between two successive client packets with data.
Situational Awareness

Level 1 SA - Perception

- The perception of elements in the environment within a volume of time and space
- Involves timely sensing, data generation, distribution, collection, combination, filtering, enhancement, processing, storage, retention and access.

Level 2 SA - Comprehension

- Understanding significance of perceived elements in relation to relevant goals and objectives.
- Involves integration, correlation, knowledge generation.

Level 3 SA - Projection of Future Status