MW-E2ED BoF

EDDY (End-to-End Diagnostic Discovery) concept and effort status

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Carnegie Mellon

Outline

- Initiative vision and direction
- Concept
- Architecture
- Campus Department/Group Involvement
- Conclusion
- Next steps

Problem

Banes of the Distributed System Diagnostician

- No access to the diagnostic data
- Discovering valuable information in a sea of data
- Correlating different diagnostic data types
- Providing evidence for non-repudiation of a diagnosis
- Finding time to create tools to transfer diagnostic knowledge to less skilled organizations and/or individuals

State of Practice

- Network, application, system and security events separate, therefore extremely difficult to correlate
- Data represents only what has faulted
- No end-to-end accountability of transactions. I.g. email, web, VoIP, intrusion

Vision

Create an activity audit ledger/application that...

- Provides a means to study the behavior of faults and anomalies
- Explores the impact of an Internet with assured electronic communications and its influence on infrastructure, security, reliability, privacy and trust
- Assures the ‘default’ electronic interaction by creating a means of non-repudiation between two or more parties

Initial Direction

Enabling mechanism for investigating,

- Machine to machine interaction
- Taxonomic risk analysis of security anomalies
- Automated diagnostic practices, not just what has faulted but how the fault occurred
- Perceived anomalies verses actual faults
- Embedded system events
- High volume event driven systems
- Rapid tool development platform for diagnostic applications

Effort Timeline

Activities	Status	Month				
		Oct – Dec 03	Jan – Jun 04	Jul – Dec 04	Jan – Jun 04	Jul – Dec 05
Startup	Done					
Discovery	Done					
Preliminary Design	Done					
Pilot Design	Done					
Pilot Implementation	Done					
Pilot Verification	Done					
Findings and Redesign	Done					
EDDY Implementation	Active					
EDDY alpha/beta	Active					
EDDY Distribution	-					

Major Milestones

- Advisory group formed
- CER conceived
- High level architecture finalized
- Pilot delivered
- EDDY backplane operational
- EDDY release

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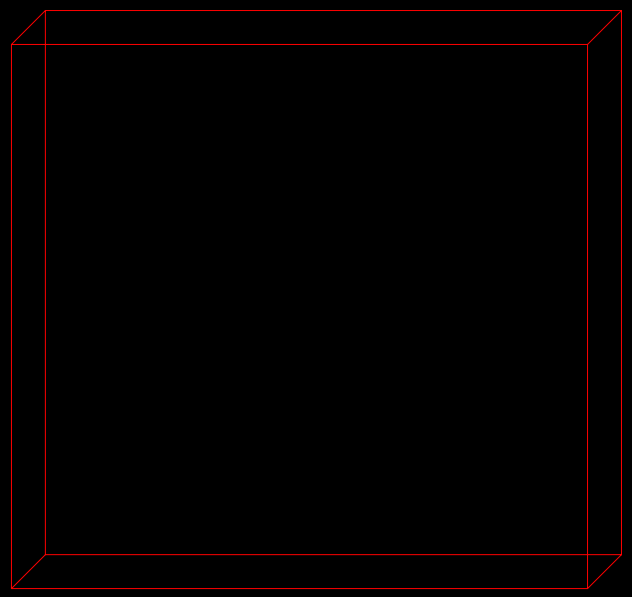
EDDY: End-to-end Diagnostic DiscoverY

Goals of the effort,

- Enable the collection of a wide array of network, system, application, security, and environmental events
- Provide a feature rich event dissemination infrastructure that can scale
- Introduce an API that enables diagnostic tool developers to build the next generation or retrofit existing tools

Separate Event Domains

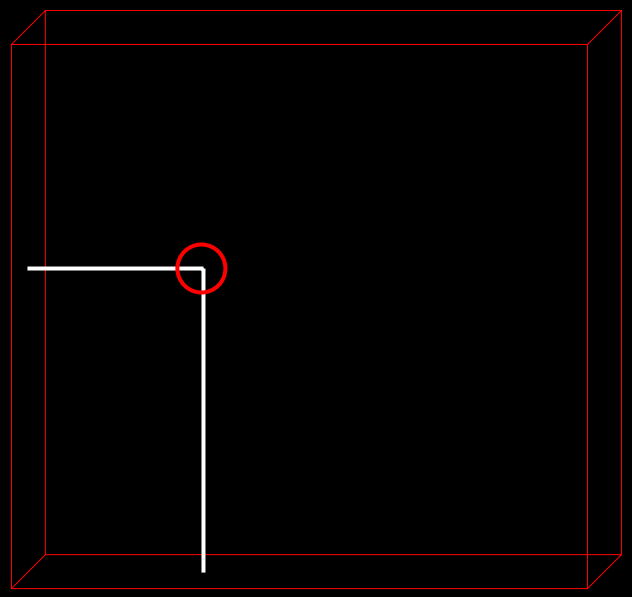
Distributed System Events



Diagnostic Tools

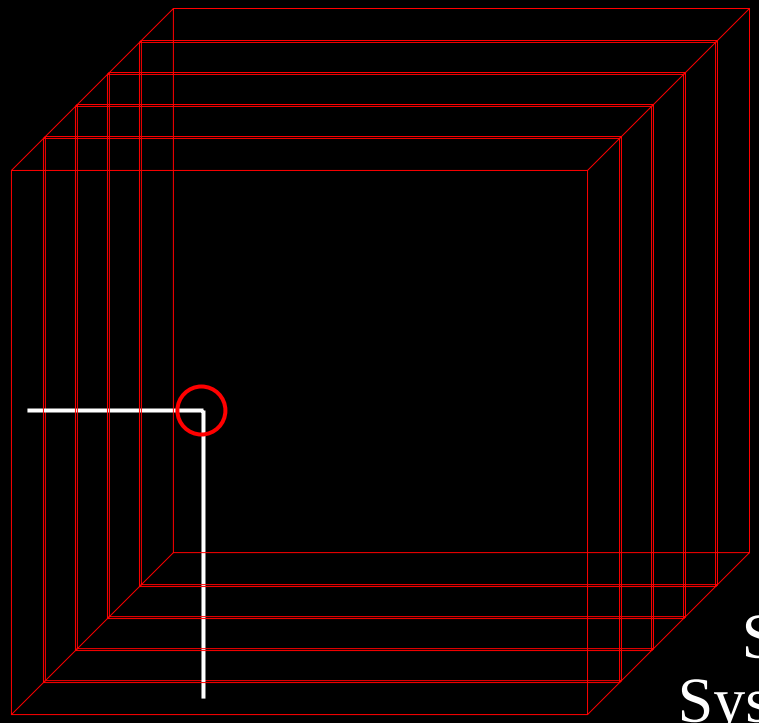
Separate Event Domains

Distributed System Events

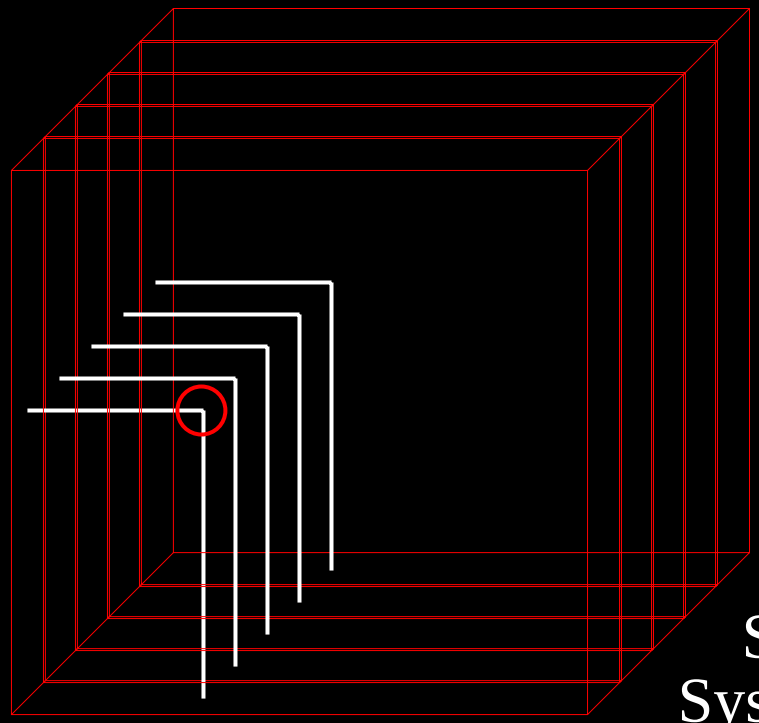


Diagnostic Tools

Separate Event Domains



Separate Event Domains

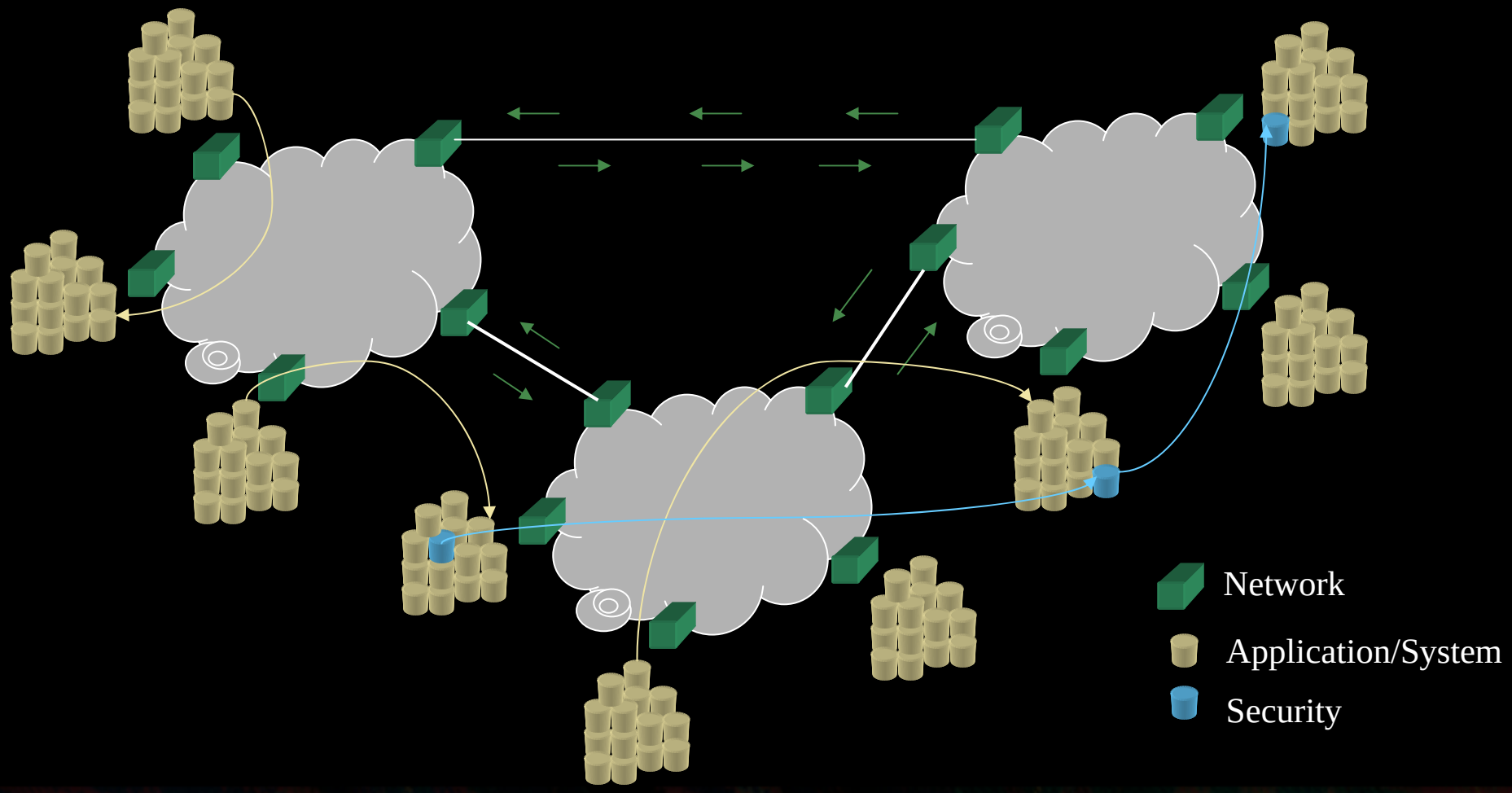


Distributed System Events

Environmental
Application
Security
System
Network

Diagnostic Tools

Separate Event Domains



Separate Event Domains

Security

- Port Scan
- Denial of Service Attack

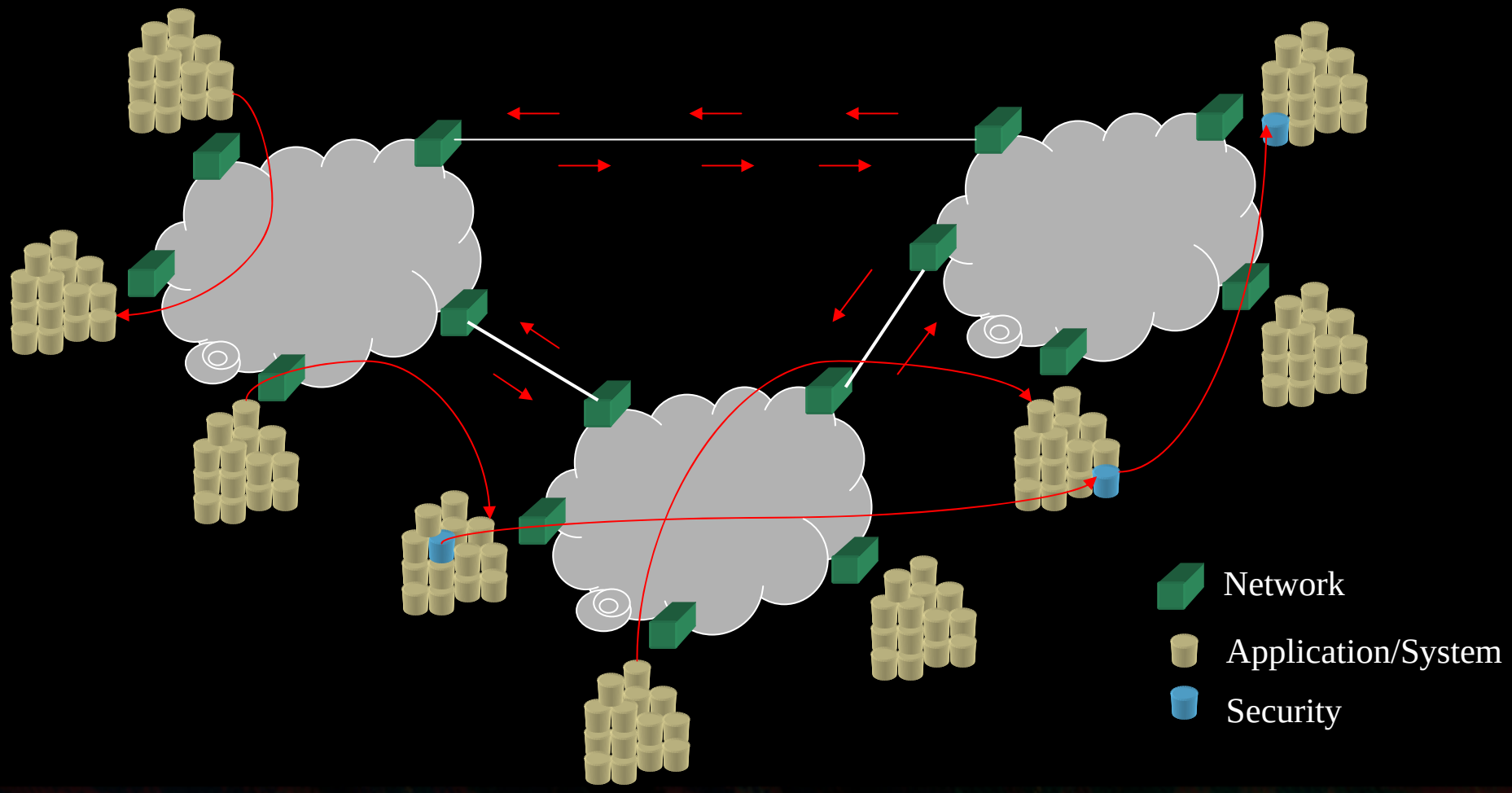
Network

- Network Transaction (Sendmail)
- Network Transaction (port 8080)
- Network Transaction (to router)

Application/System

- Sendmail Process Dies
- Sendmail Process Restarted

Combined Event Domains



EDDY Event Evolution

Security

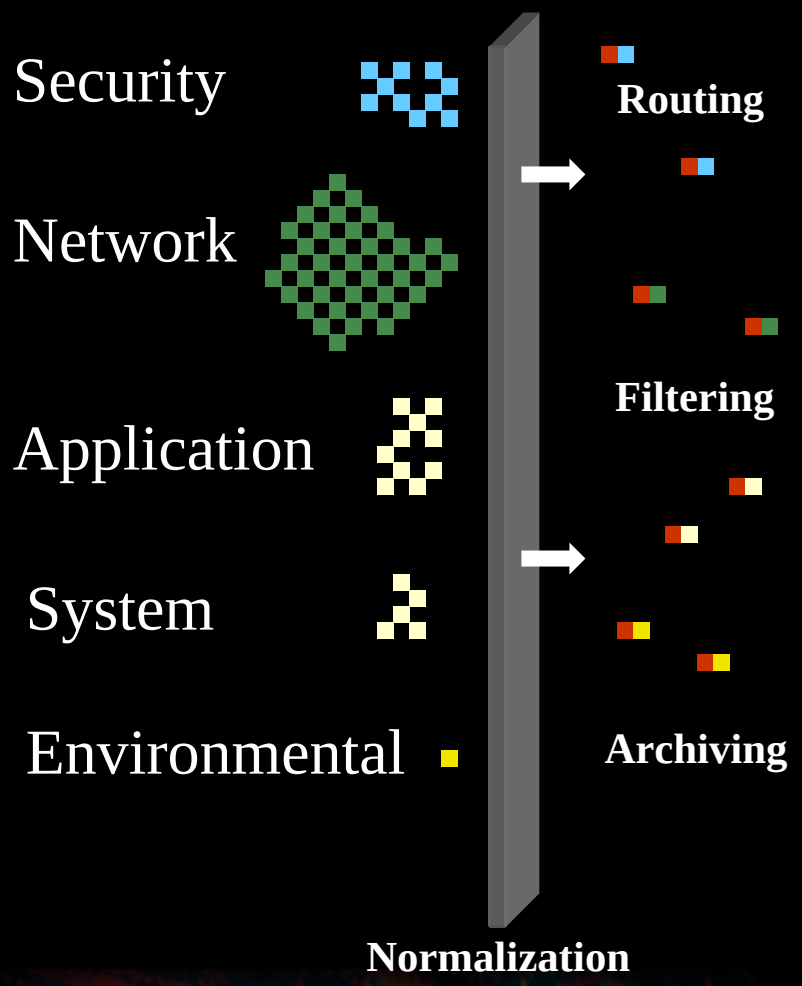
Network

Application

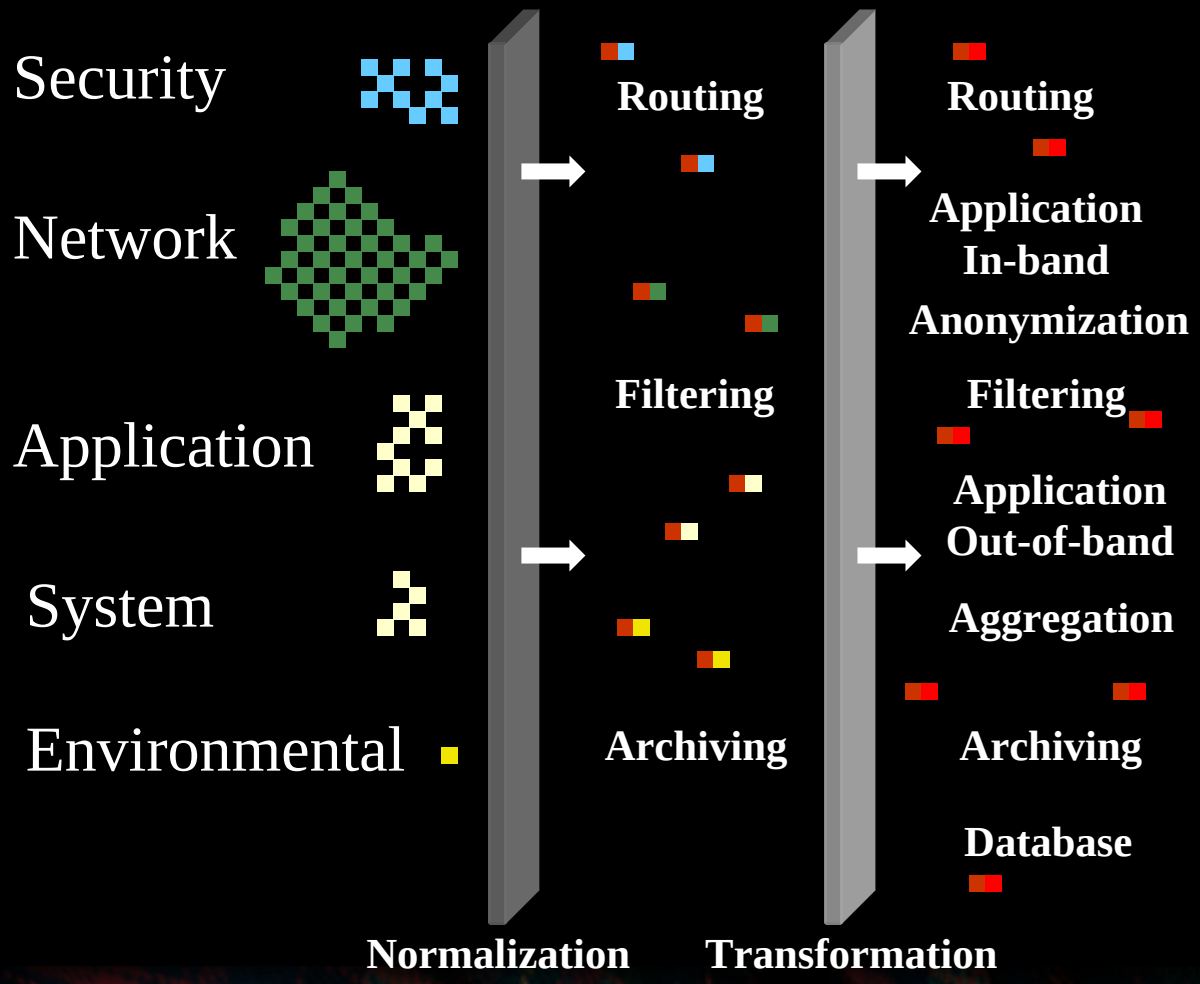
System

Environmental

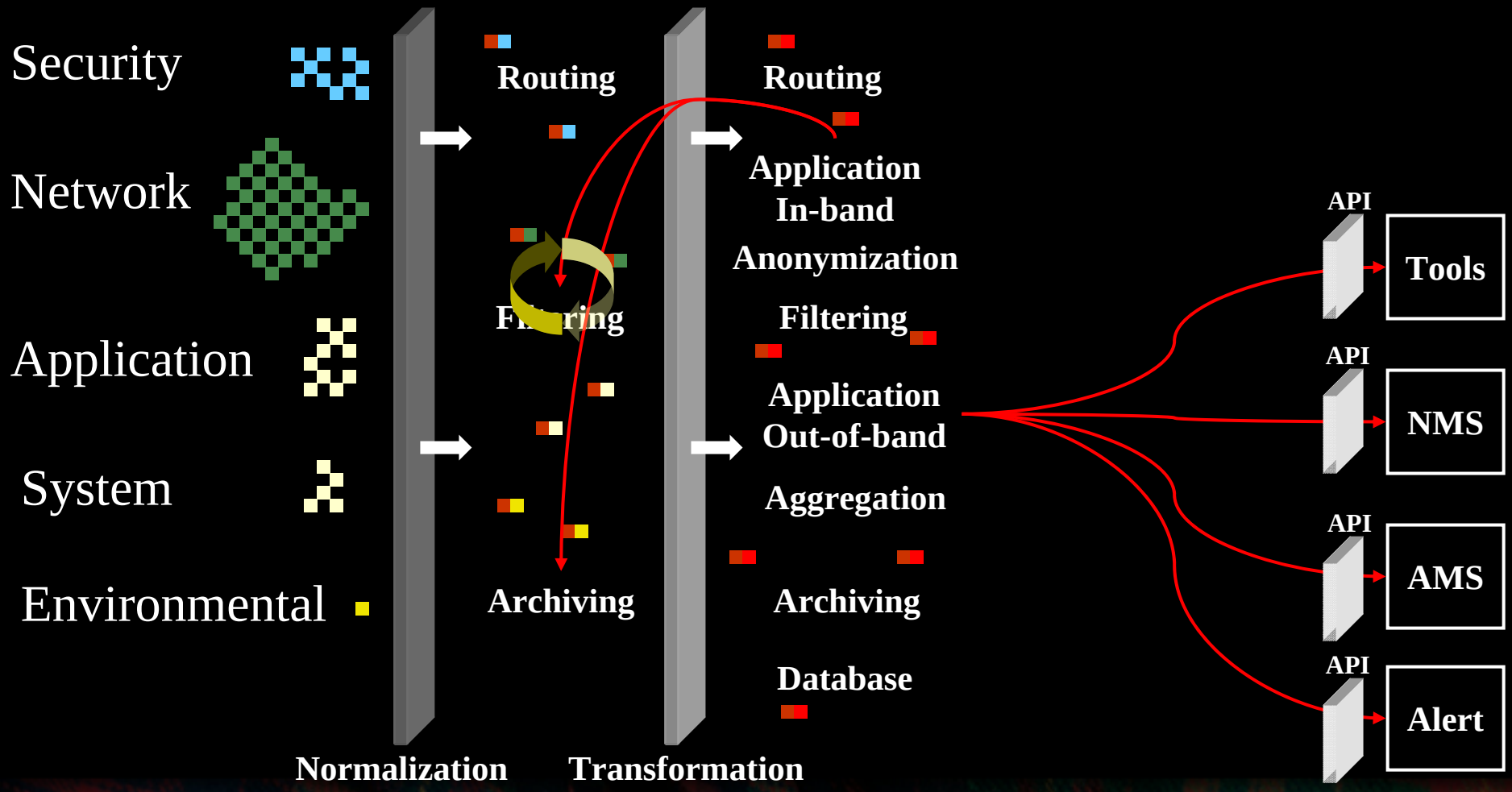
EDDY Event Evolution



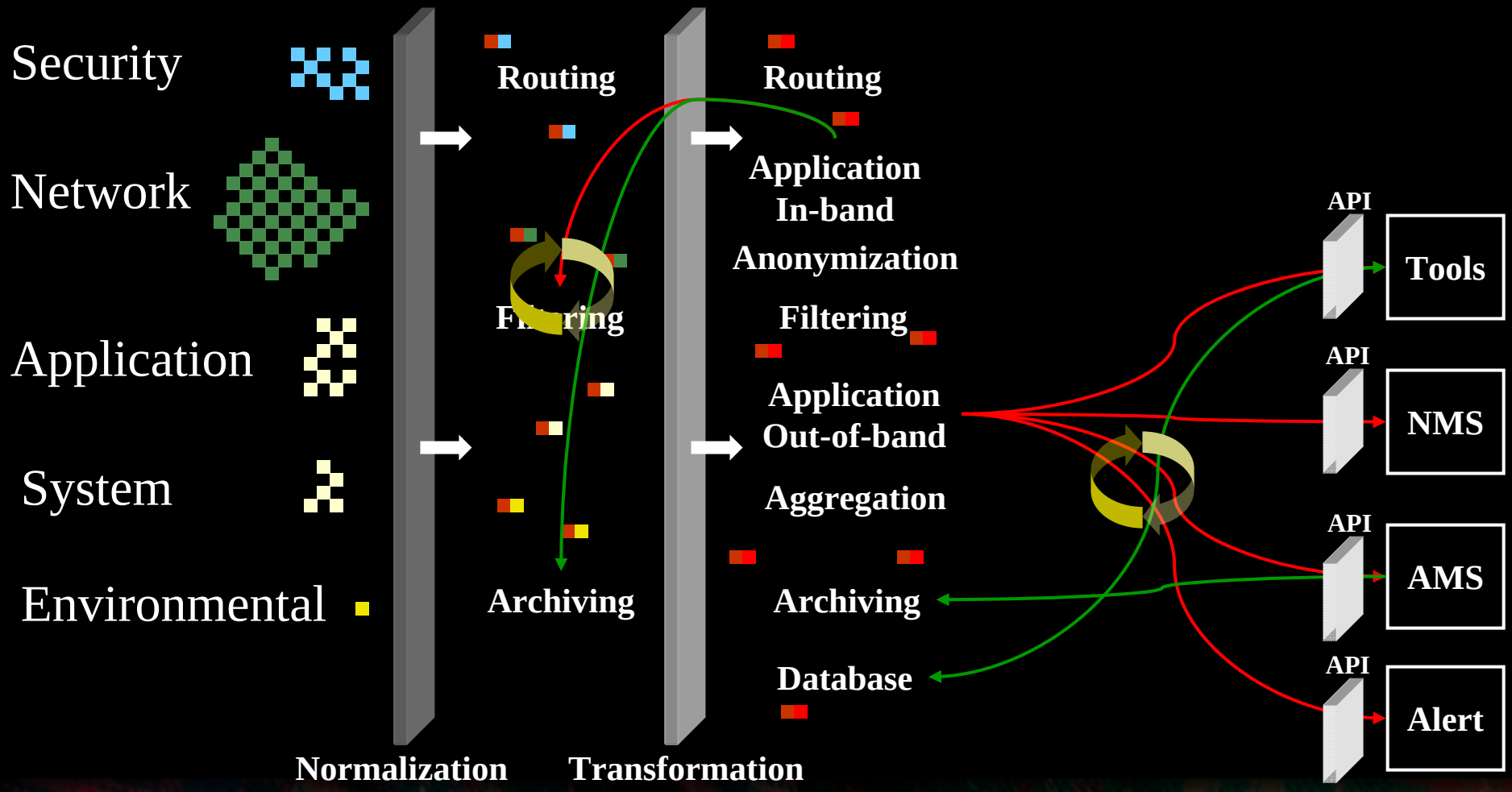
EDDY Event Evolution



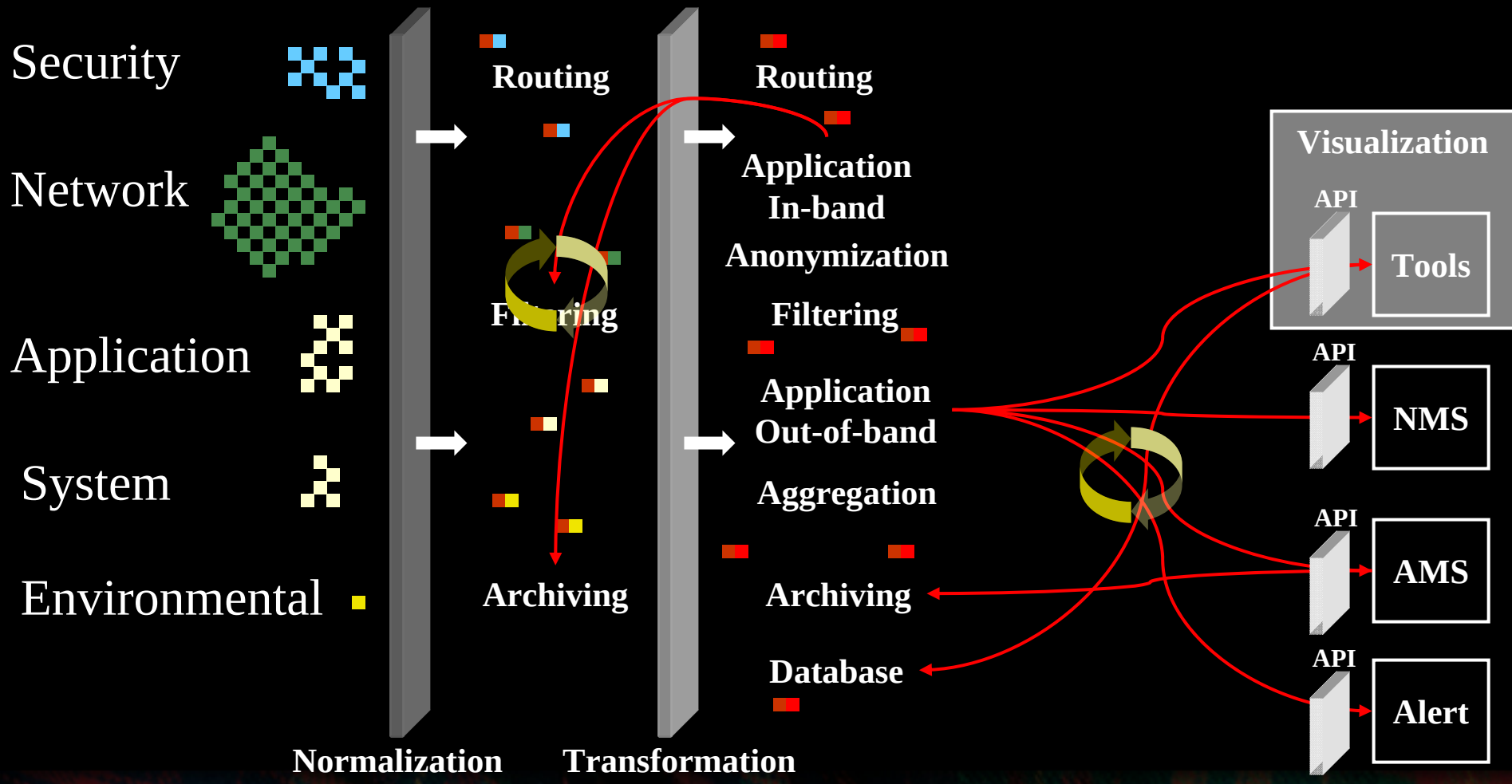
EDDY Event Evolution



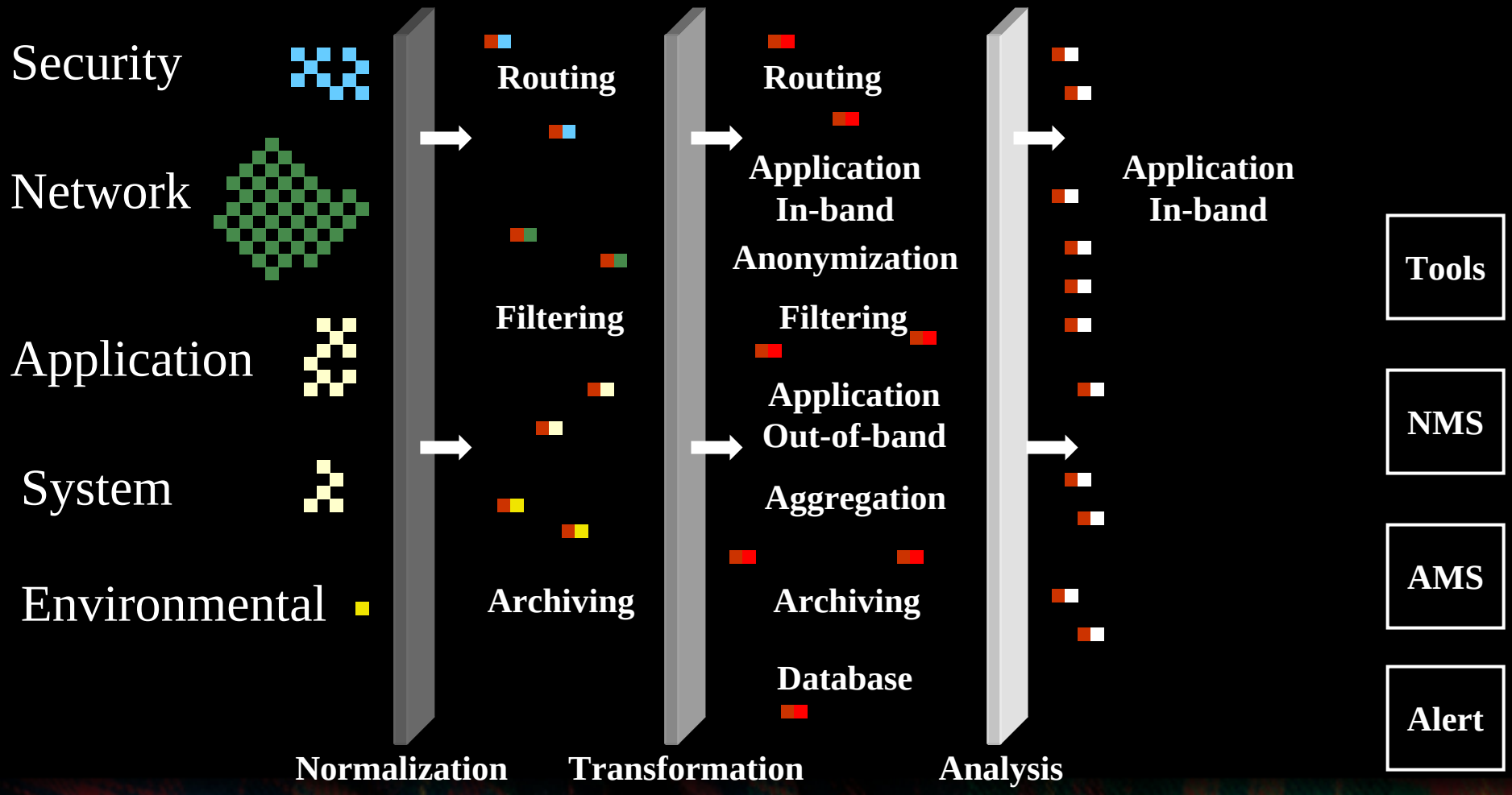
EDDY Event Evolution



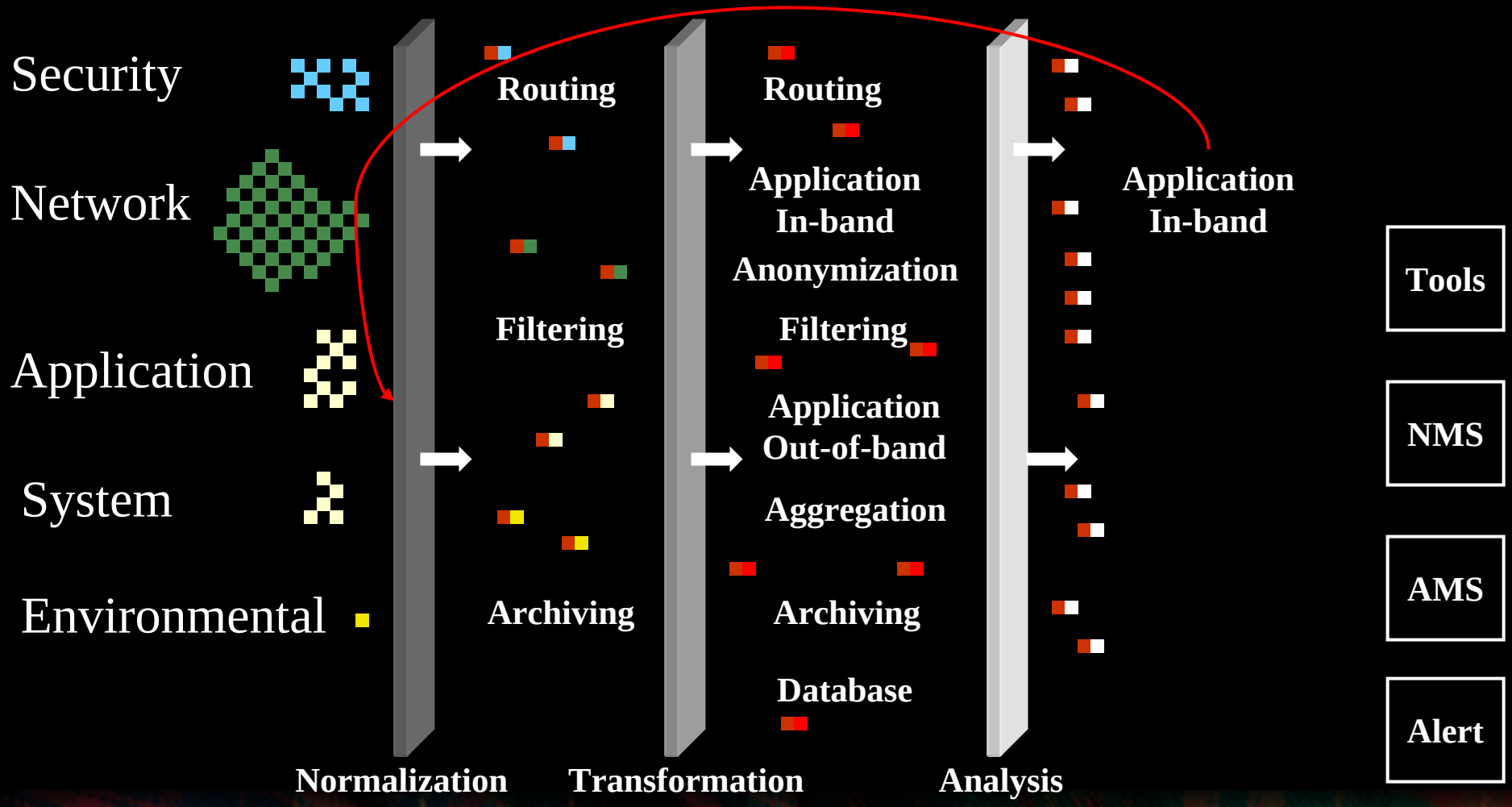
EDDY Event Evolution



EDDY Event Evolution



EDDY Event Evolution



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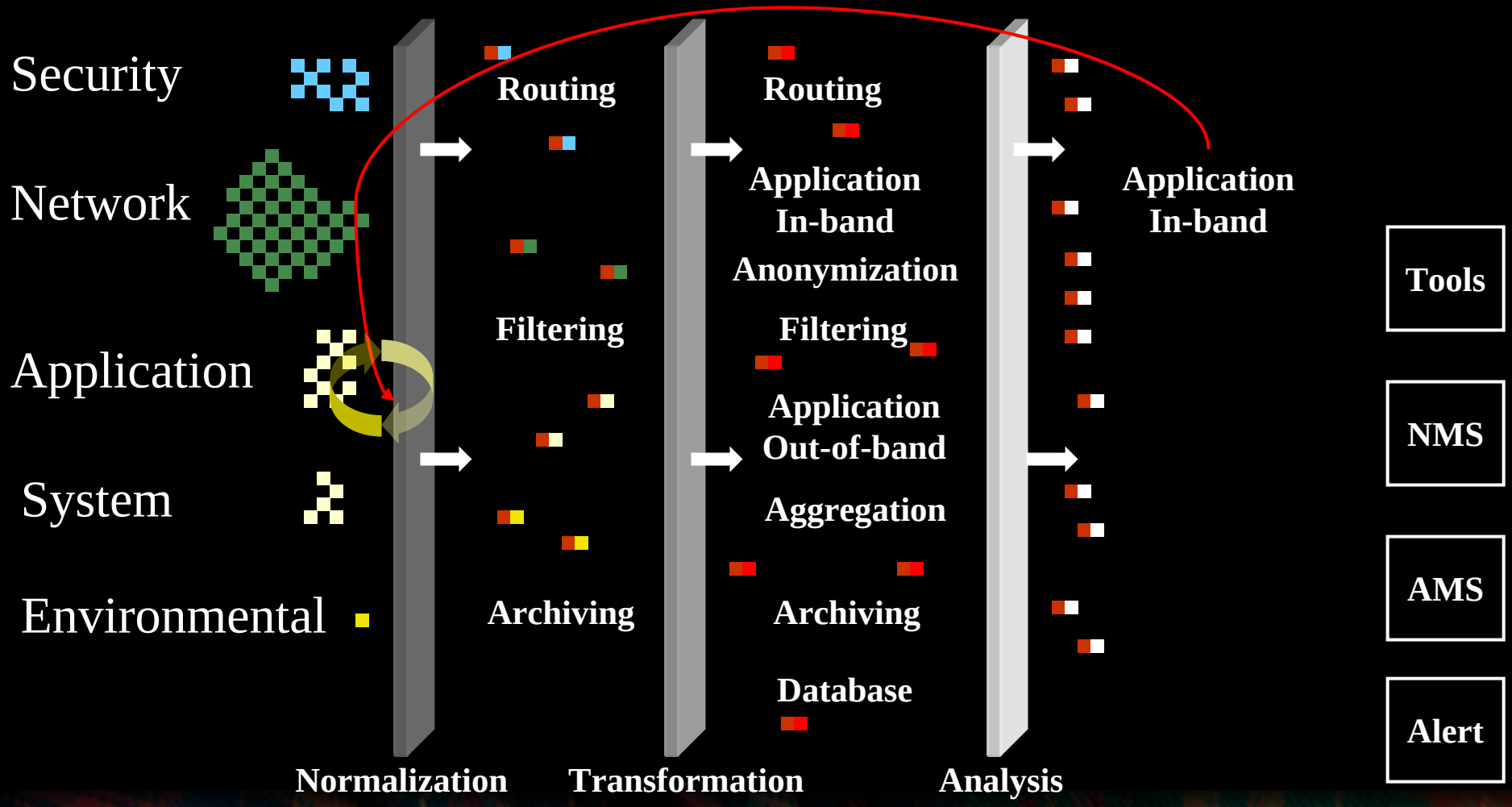

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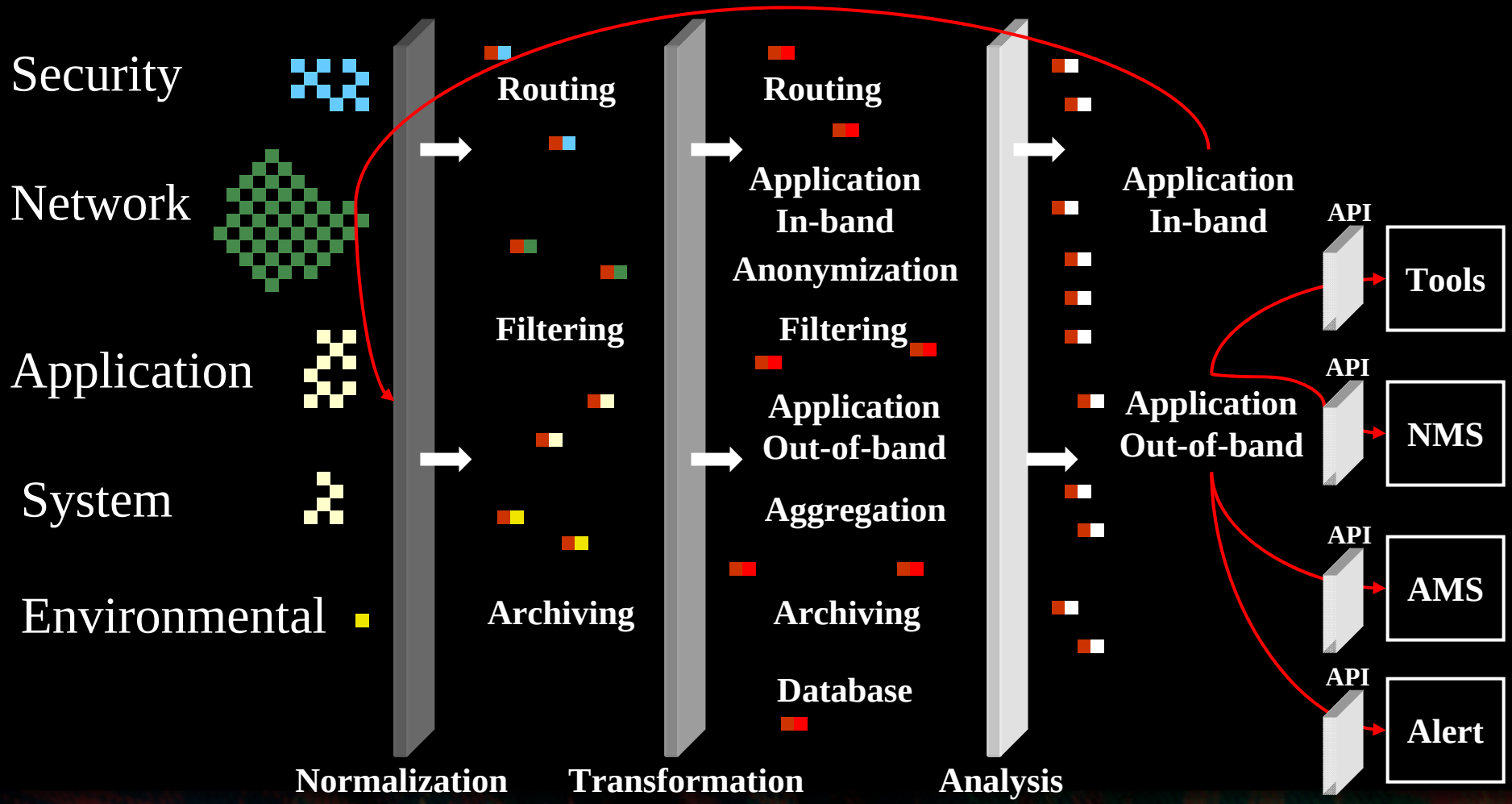
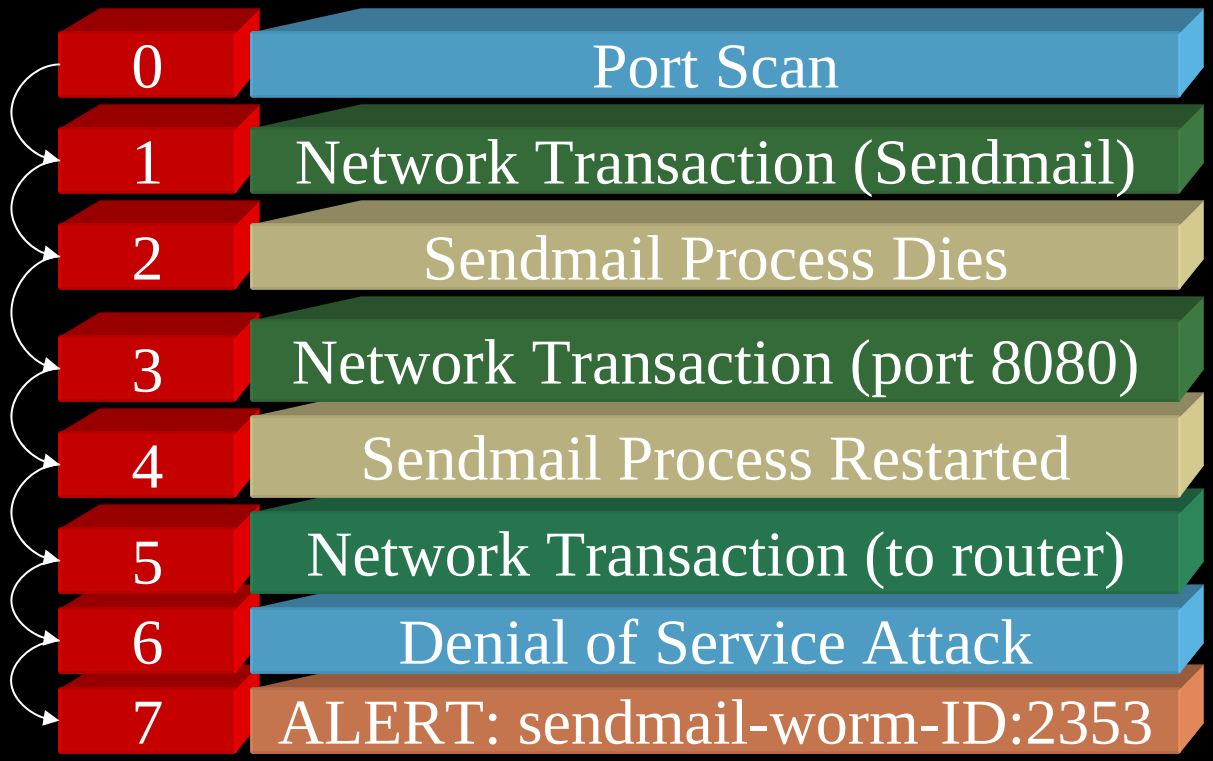
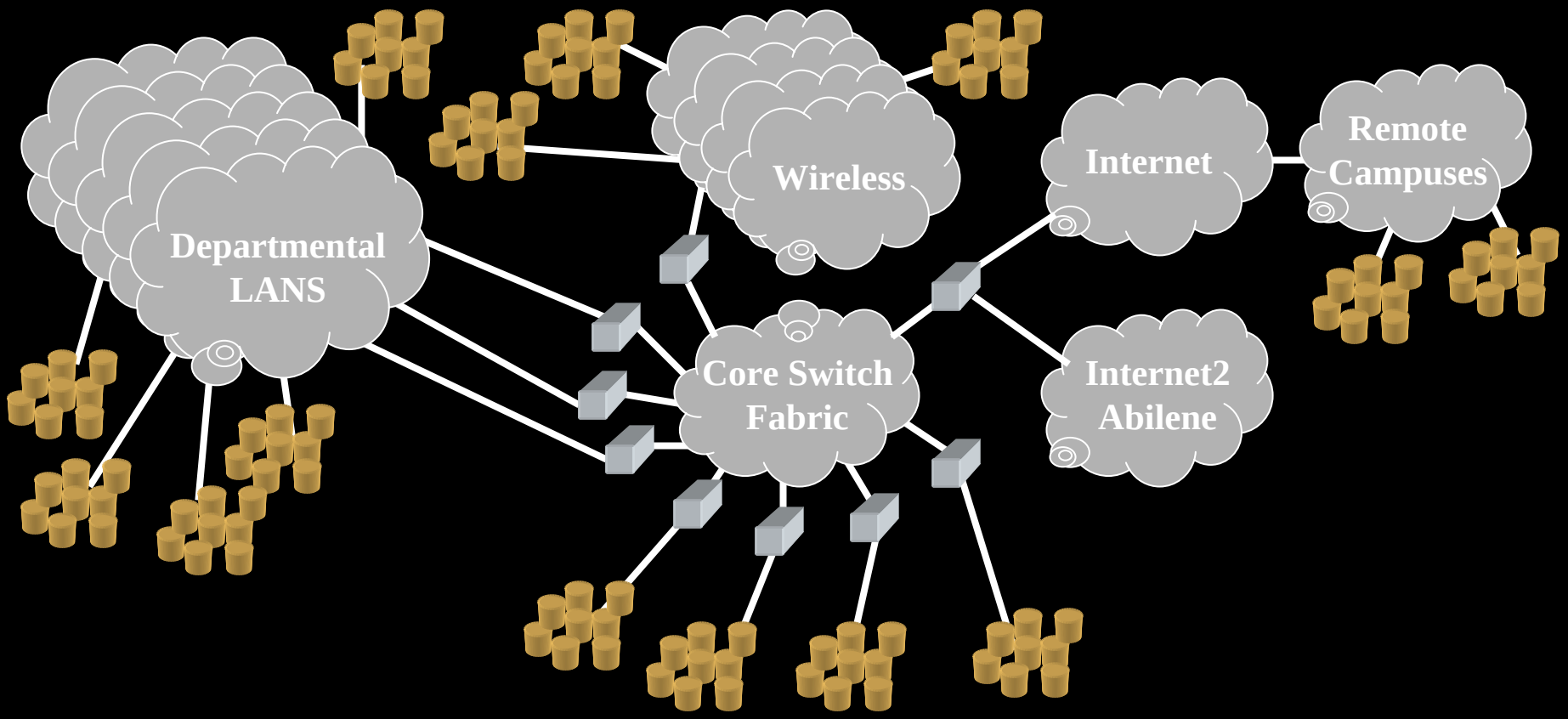


Combined Event Domains



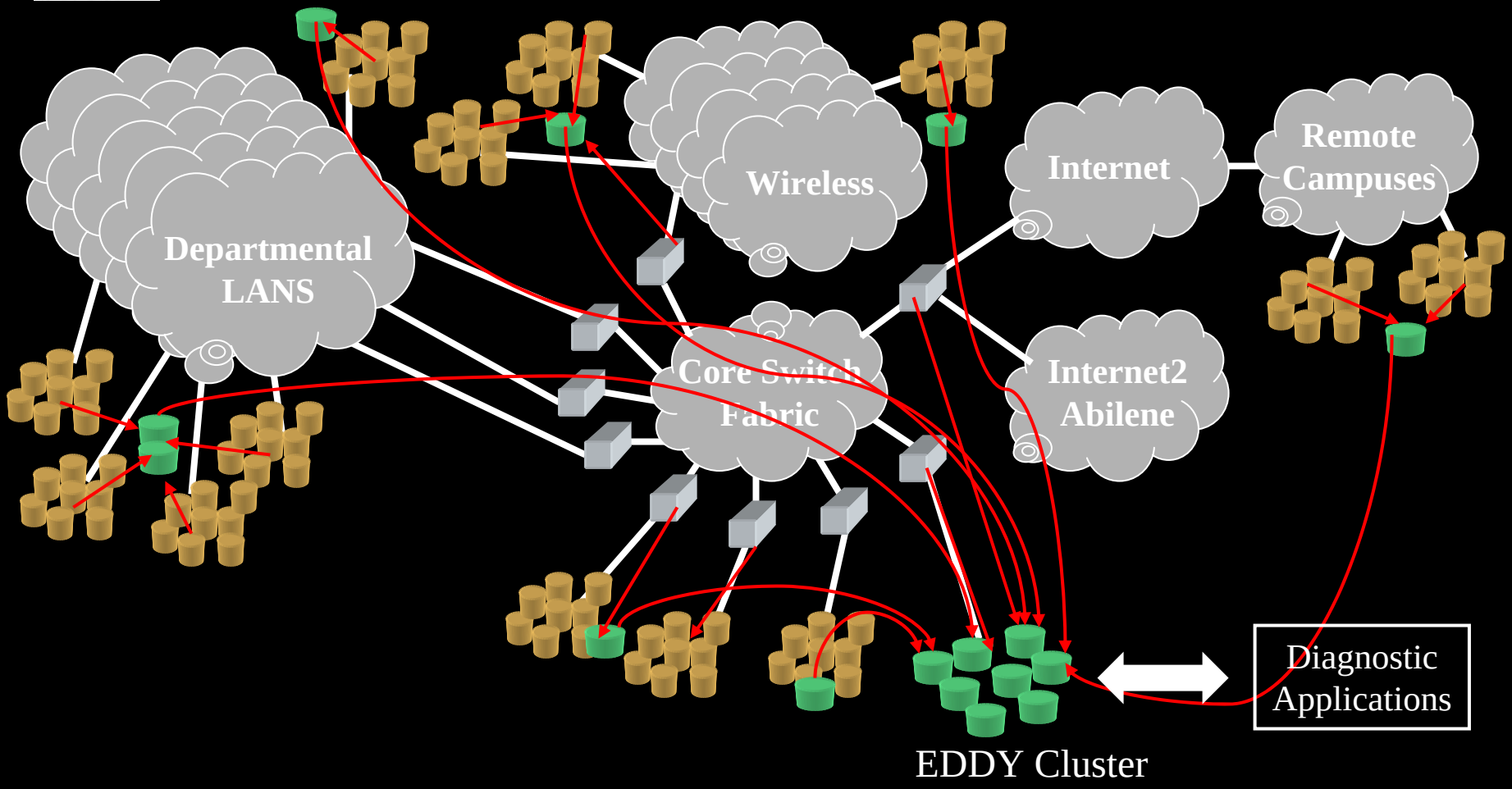
Enterprise Implementation



Edge Hosts

Backplane Hosts

Enterprise Implementation



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Backplane Hosts

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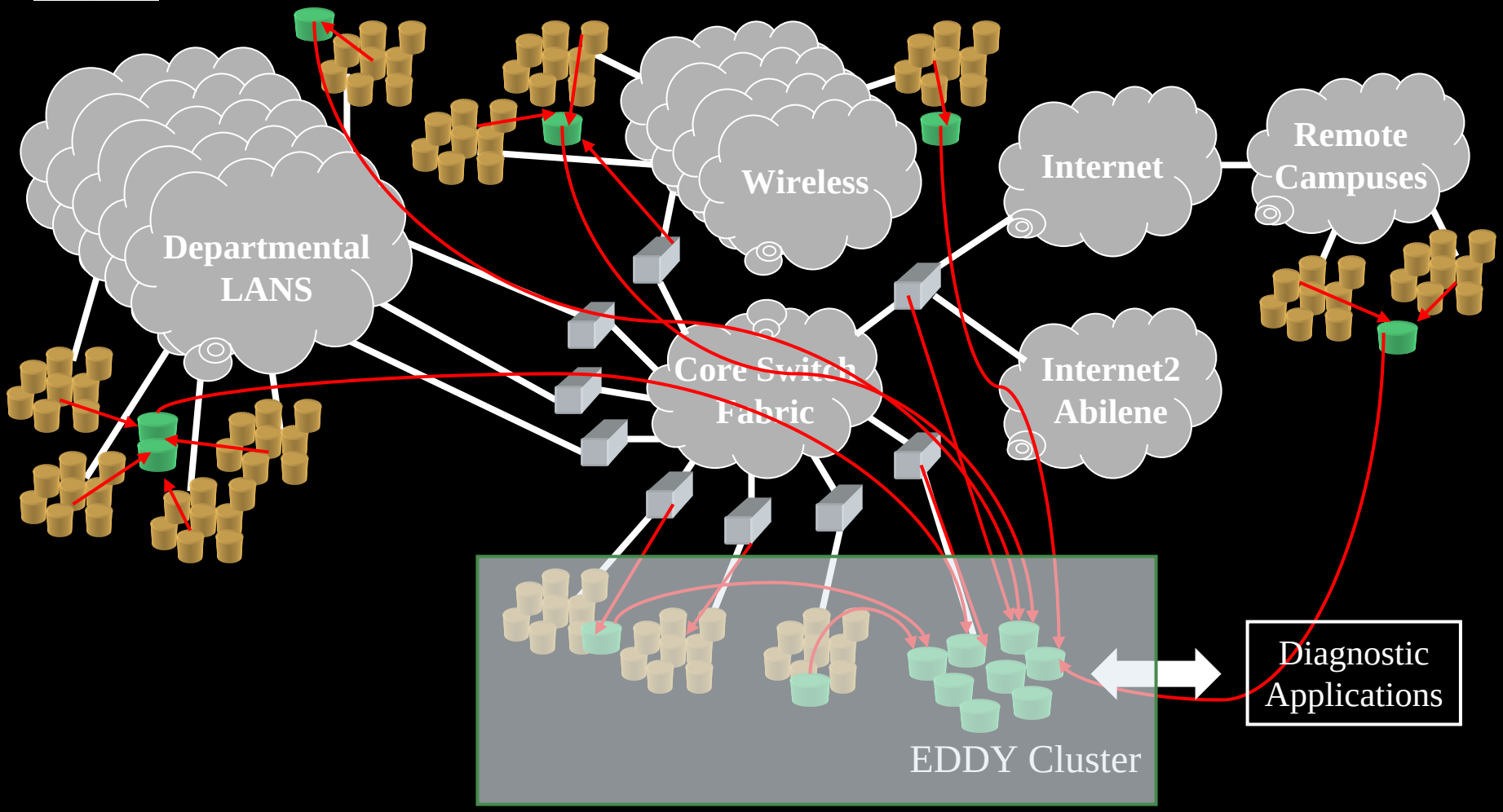
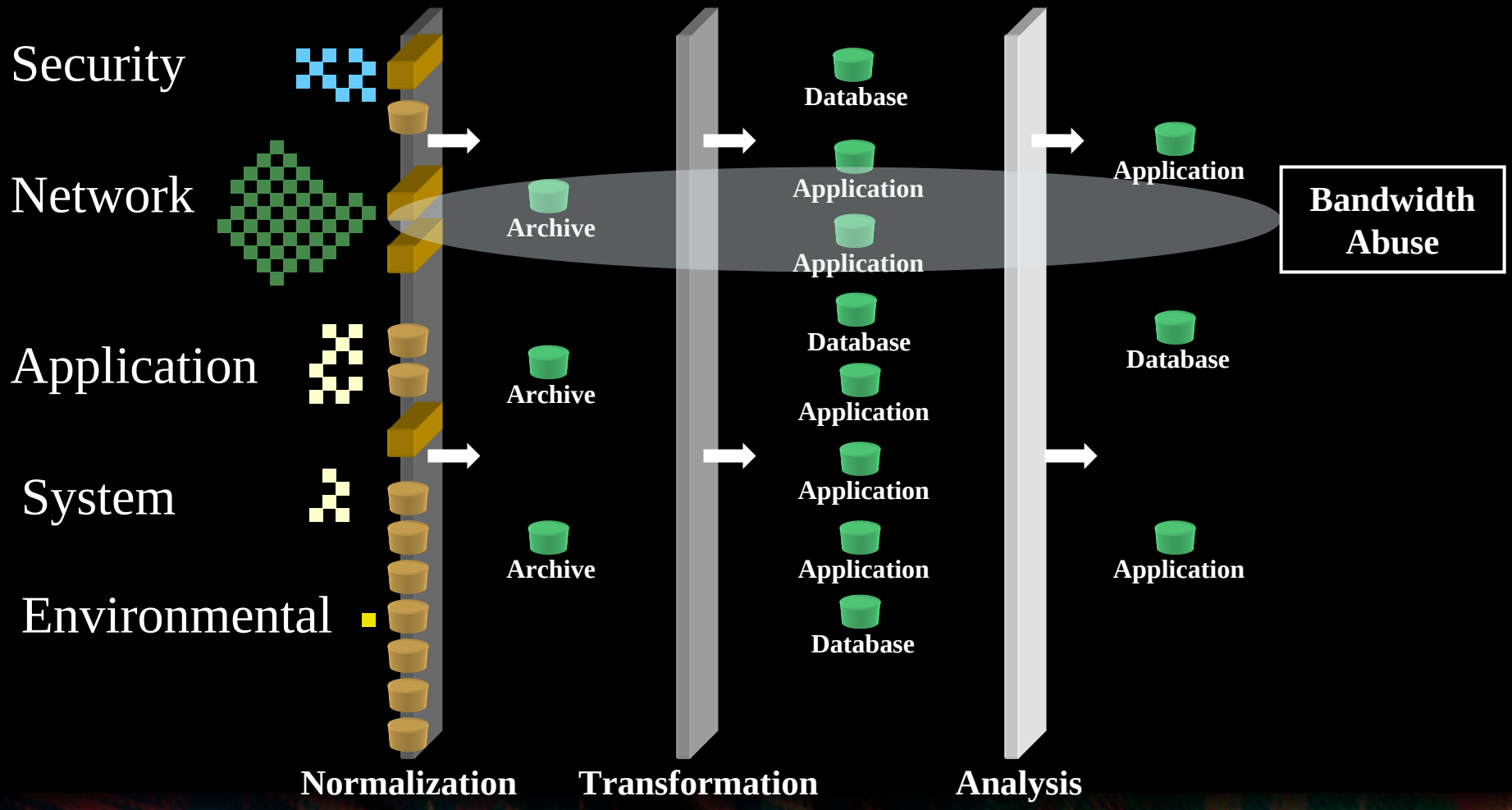


Edge Hosts

Backplane Hosts

EDDY Cluster Functionality



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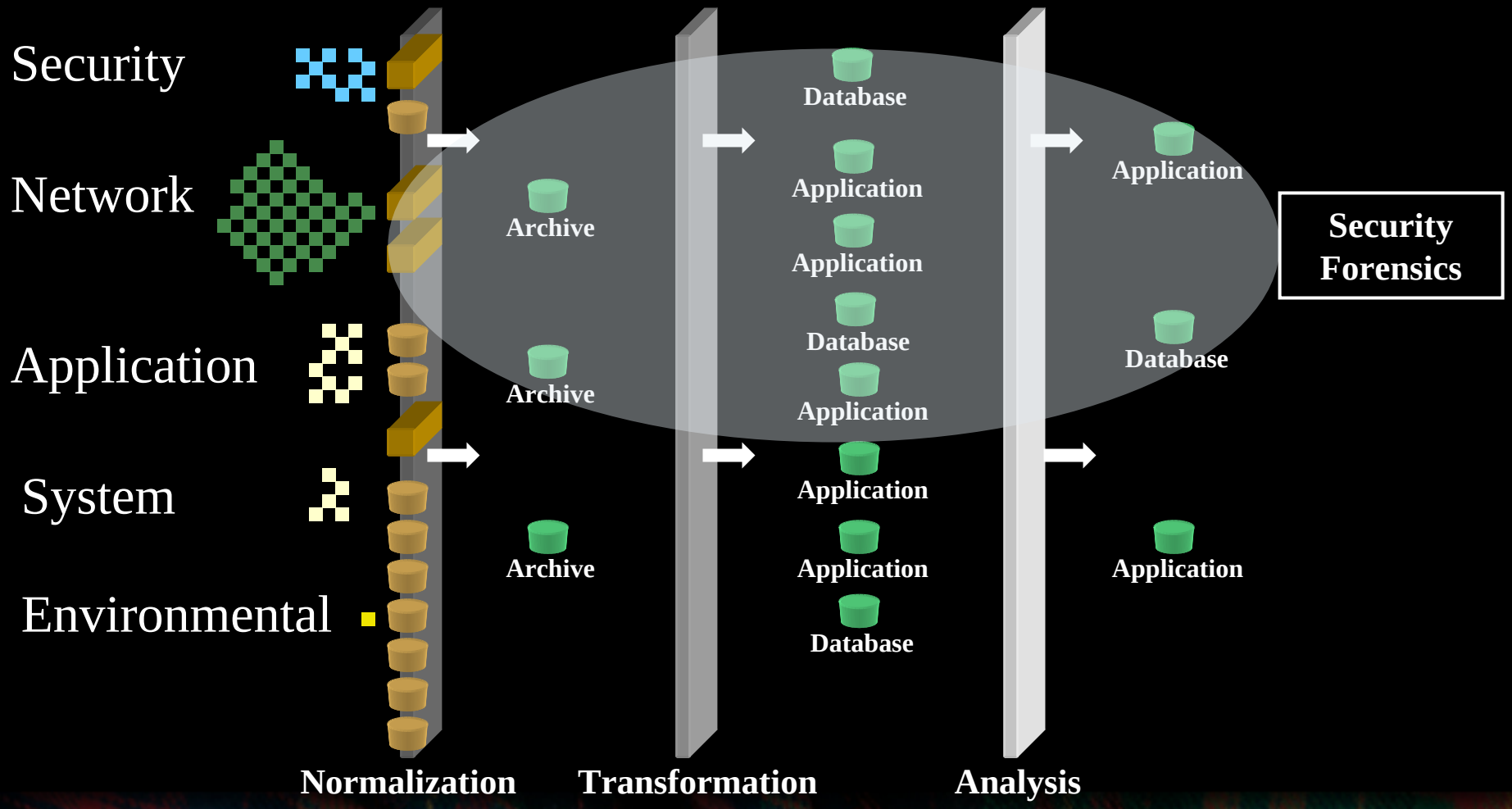
EDDY Cluster Functionality



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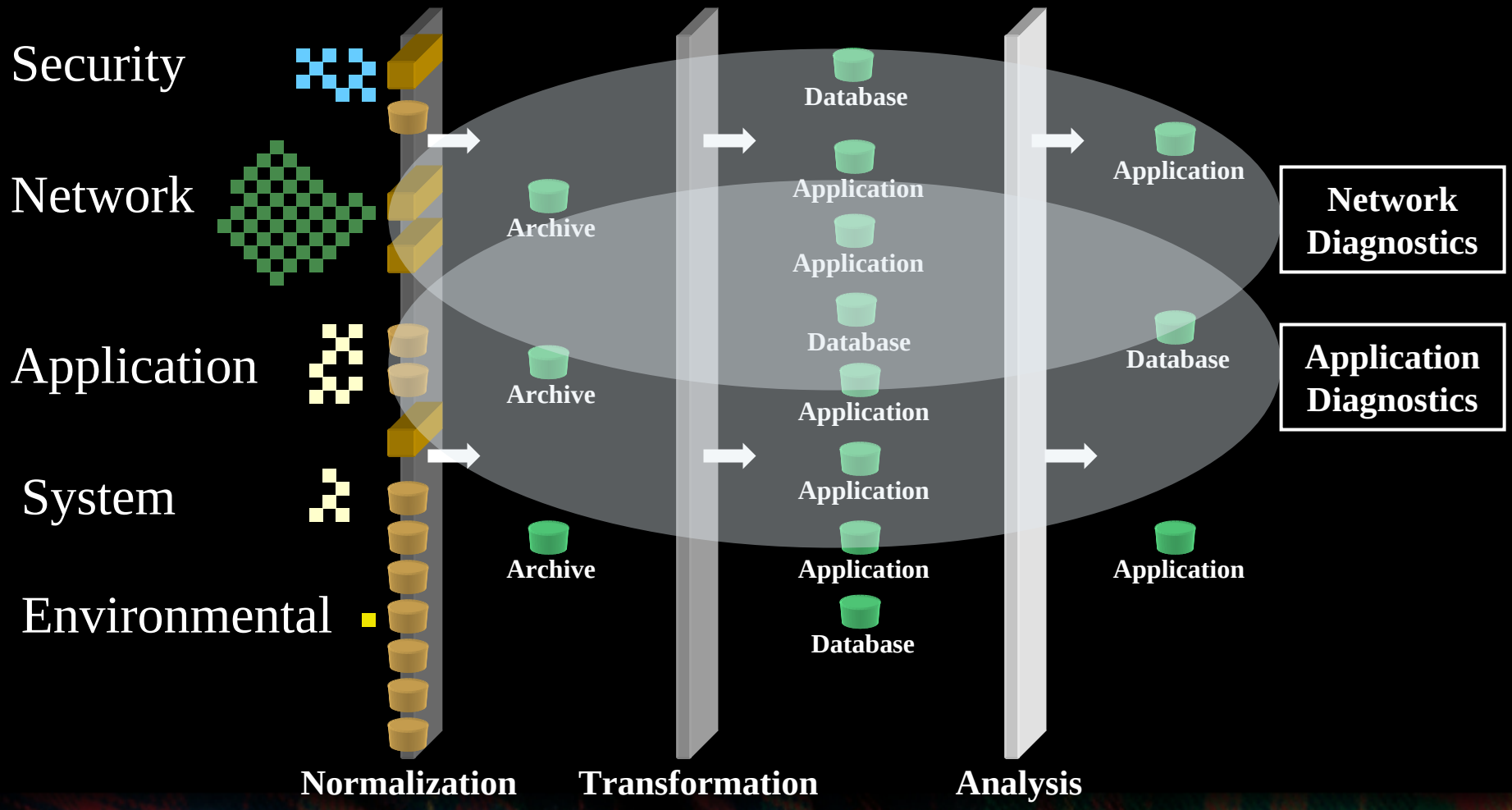

Edge Nodes

Backplane Nodes

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The Scale Issue

- Scaleable store and forward
  - Project only what is needed to the next level
  - Select back to get data that you don’t have
  - Only cook data that you need
- Data lifecycle

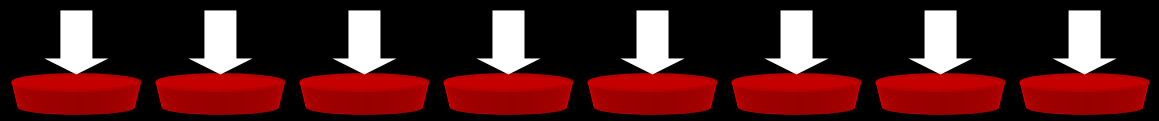
The Scale Issue

Events 5k/sec

The Scale Issue

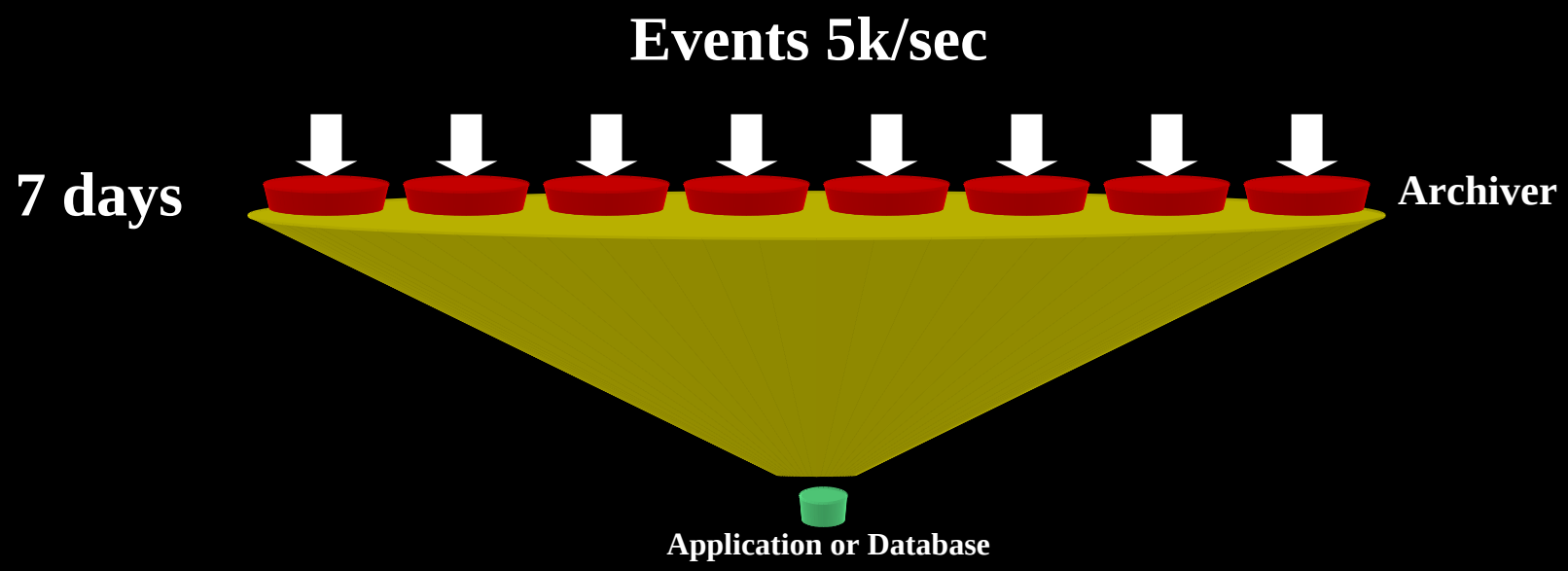
Events 5k/sec

7 days

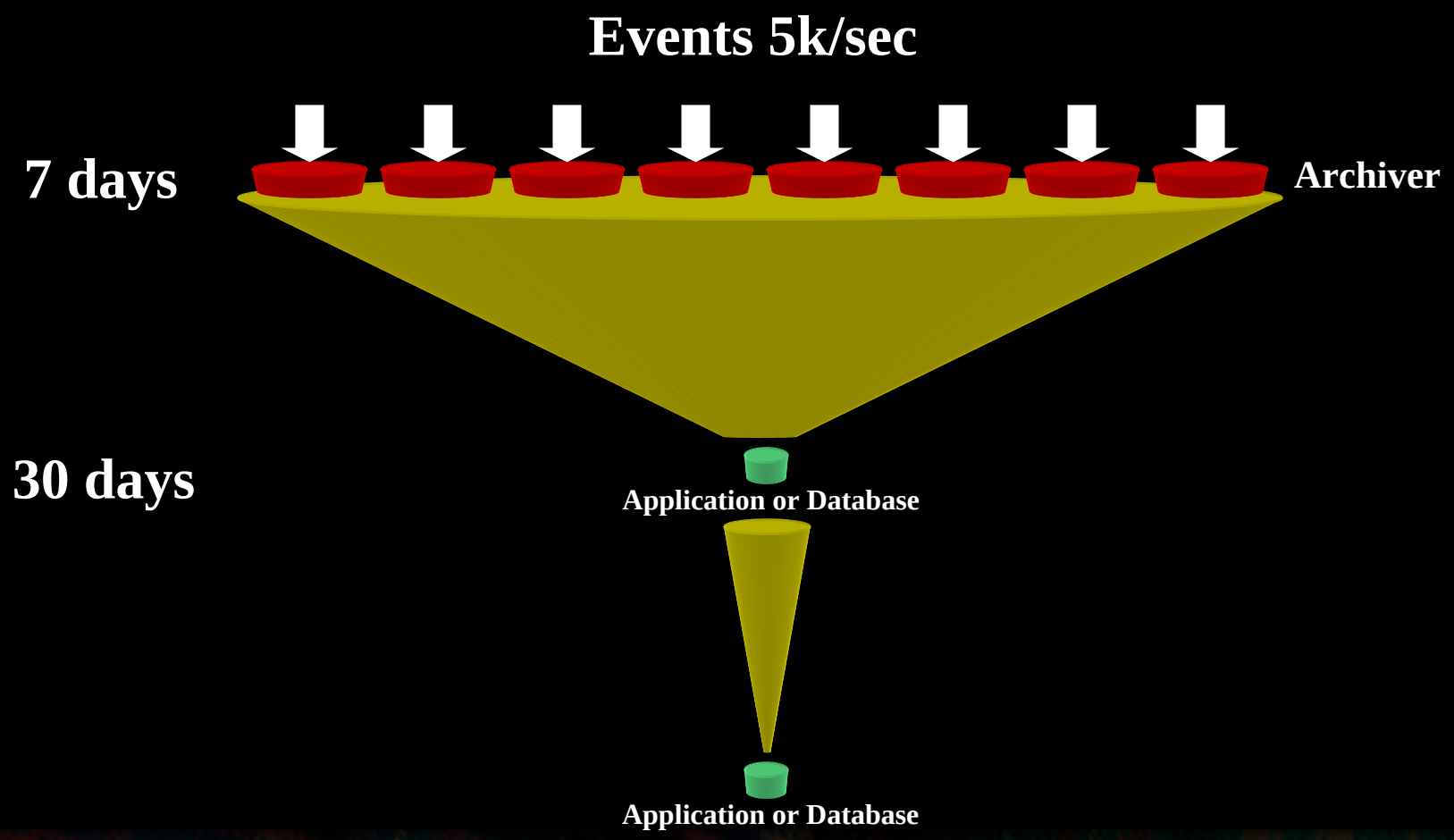


Archiver

The Scale Issue



The Scale Issue



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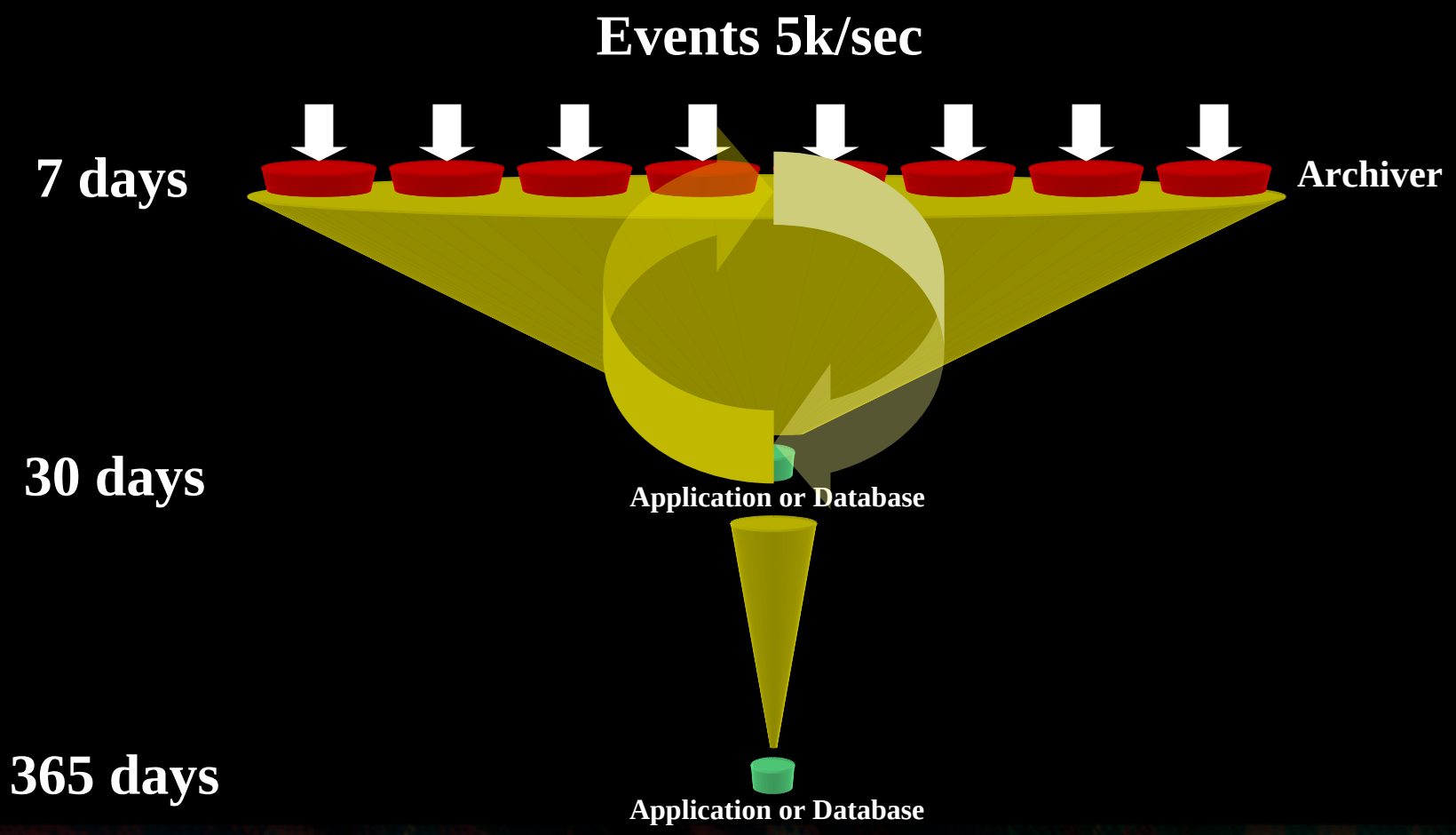
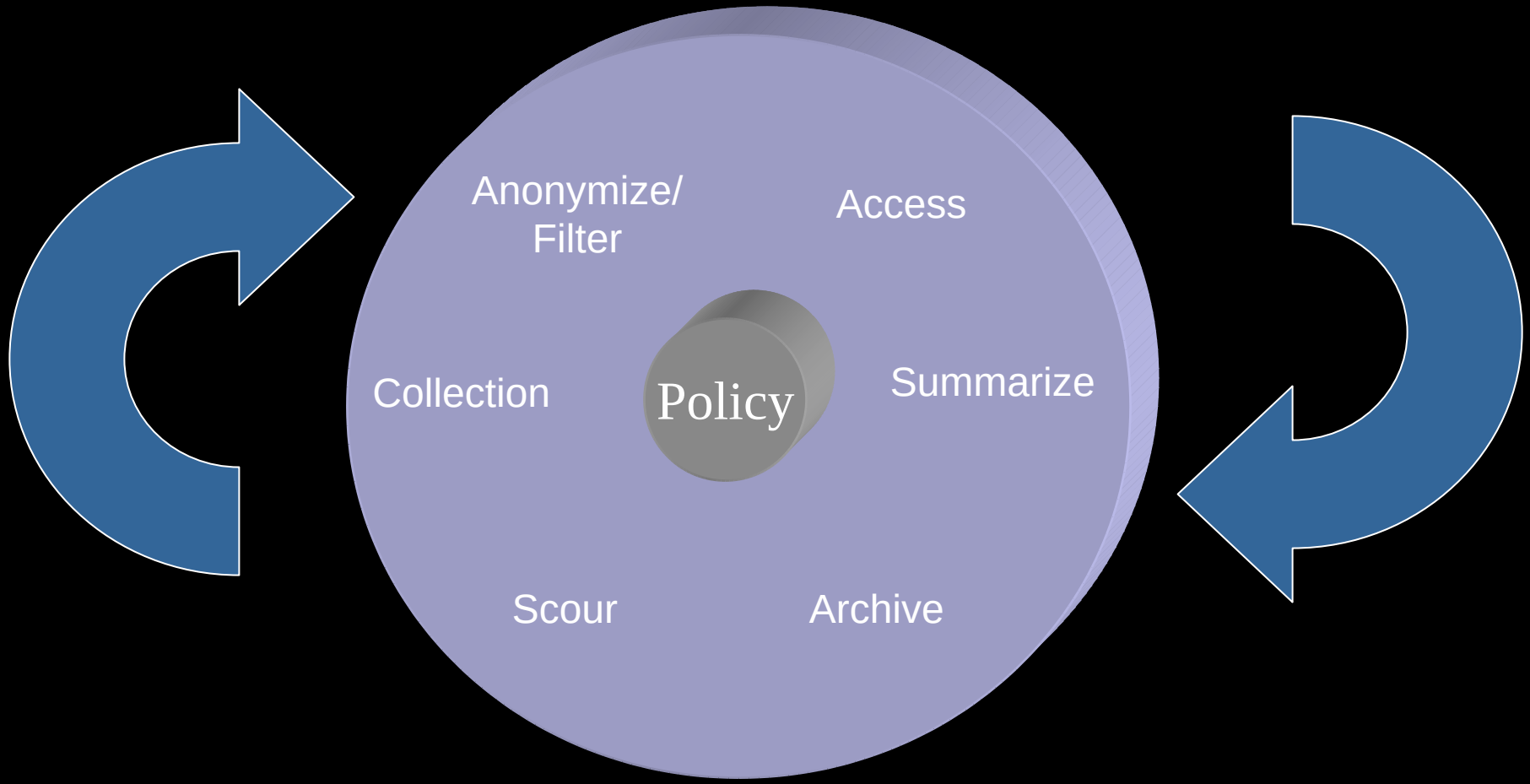


Diagnostic Data Lifecycle



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Solution

- Import a wide variety of event data easily
- Disseminate the events to elements in a distributed backplane that provides core functionality for diagnostics
- Provide access to the diagnostic data and a platform for rapid tool development

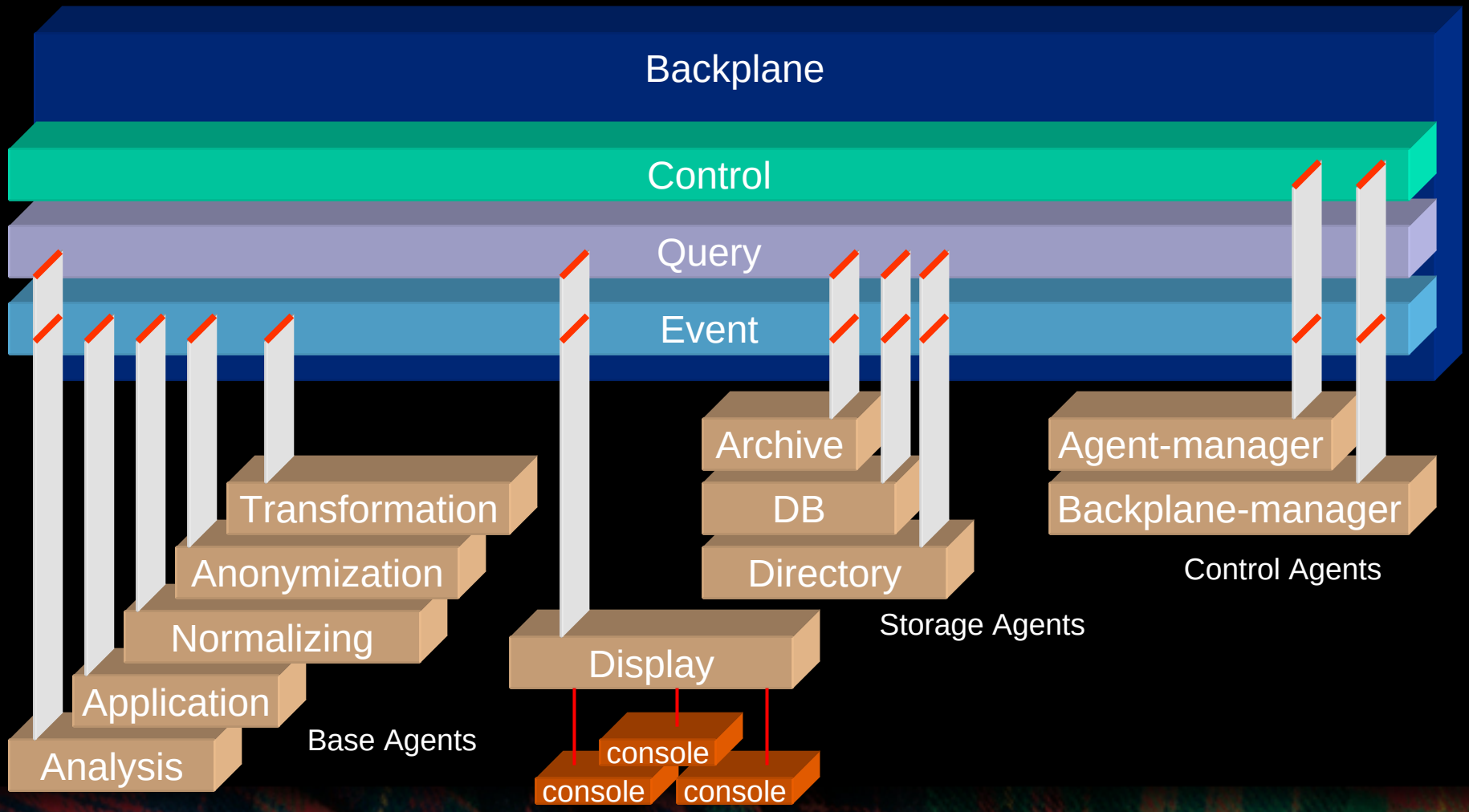
Diagnostic Backplane

- Accommodates a wide variety of event classes easily
- Enables most any device to produce events
- Supports extensible classification models
- Event routing via simple select/project functionality

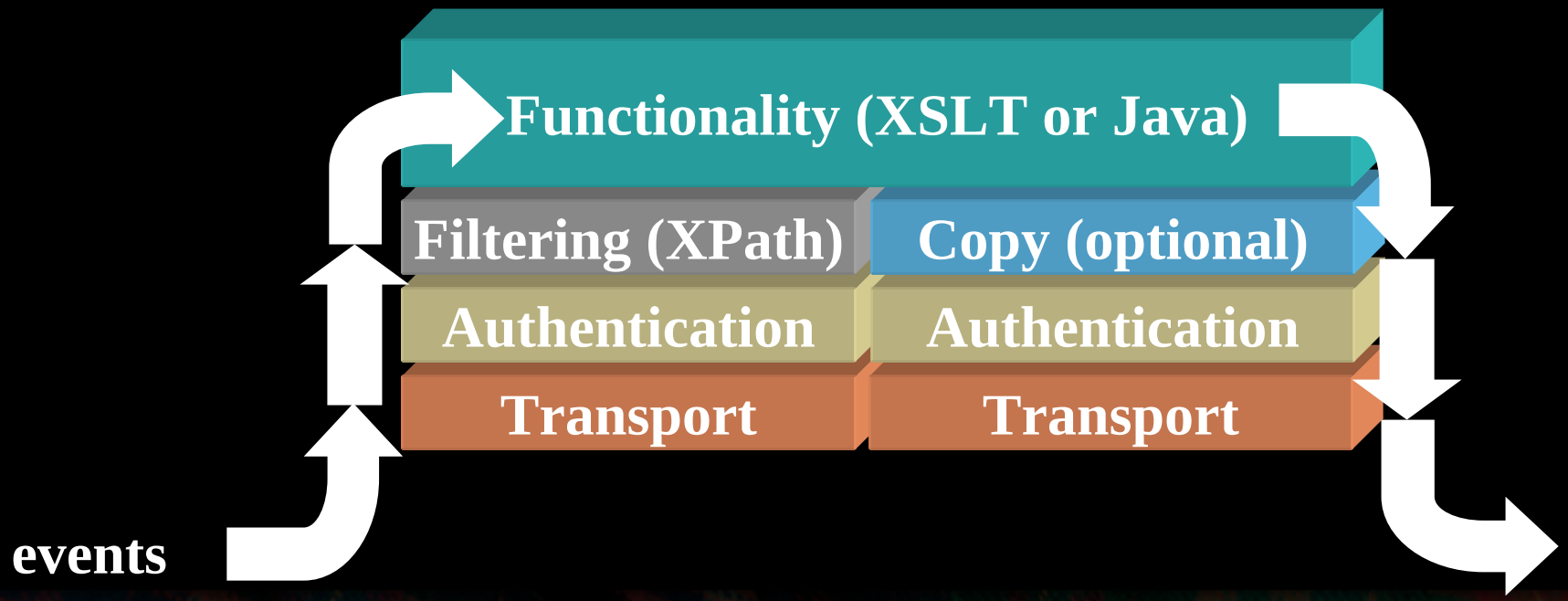
Diagnostic Backplane Cont.

- Edge hosts:
  - Servers, clients, and embedded devices
  - Indirectly collecting flow and security data from switches, routers and security devices
- Backplane hosts:
  - Forward, manipulate and store event flows from edge hosts
  - provide an API to query backplane for event information
  - Control and mange the backplane itself

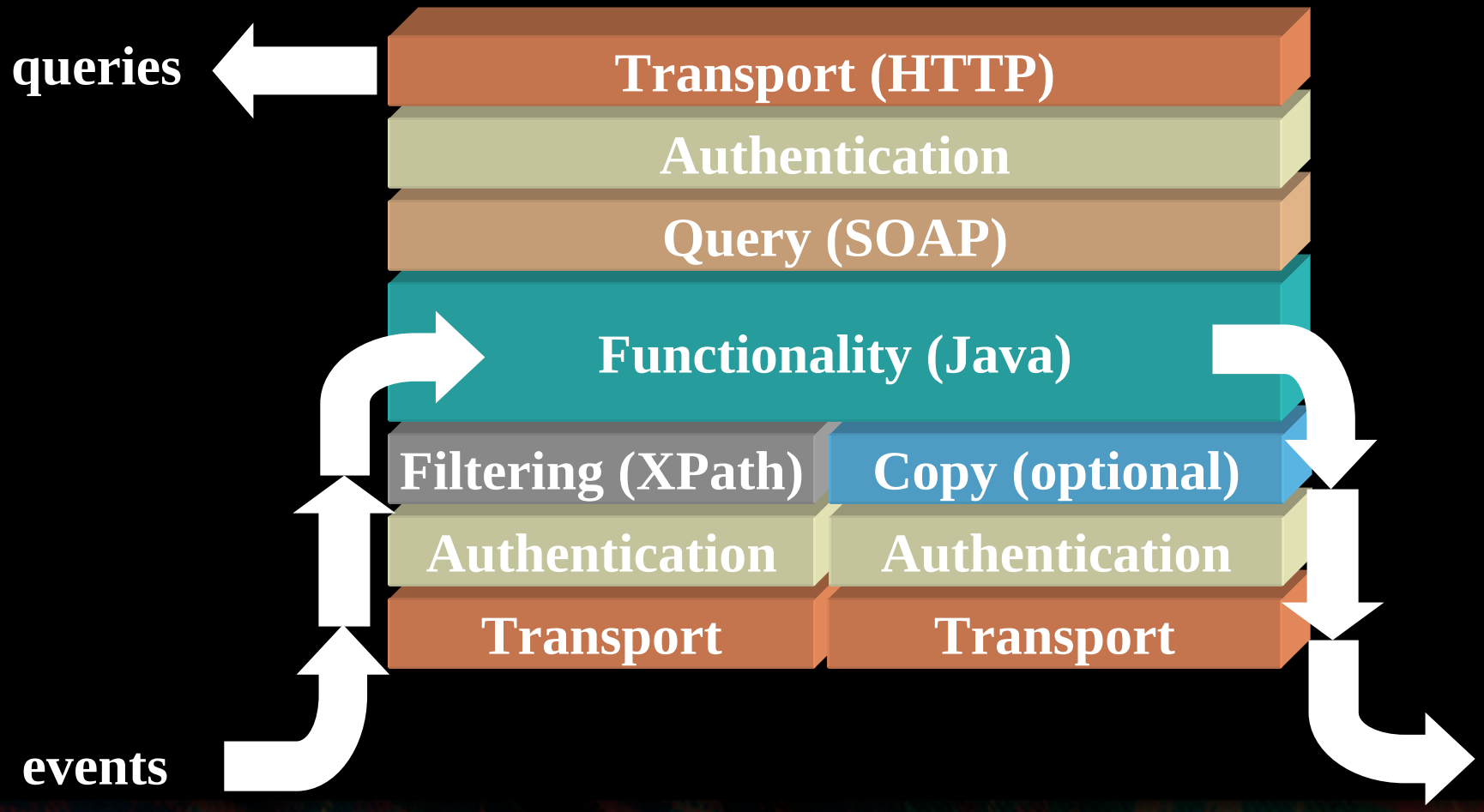
Backplane Transport Channels



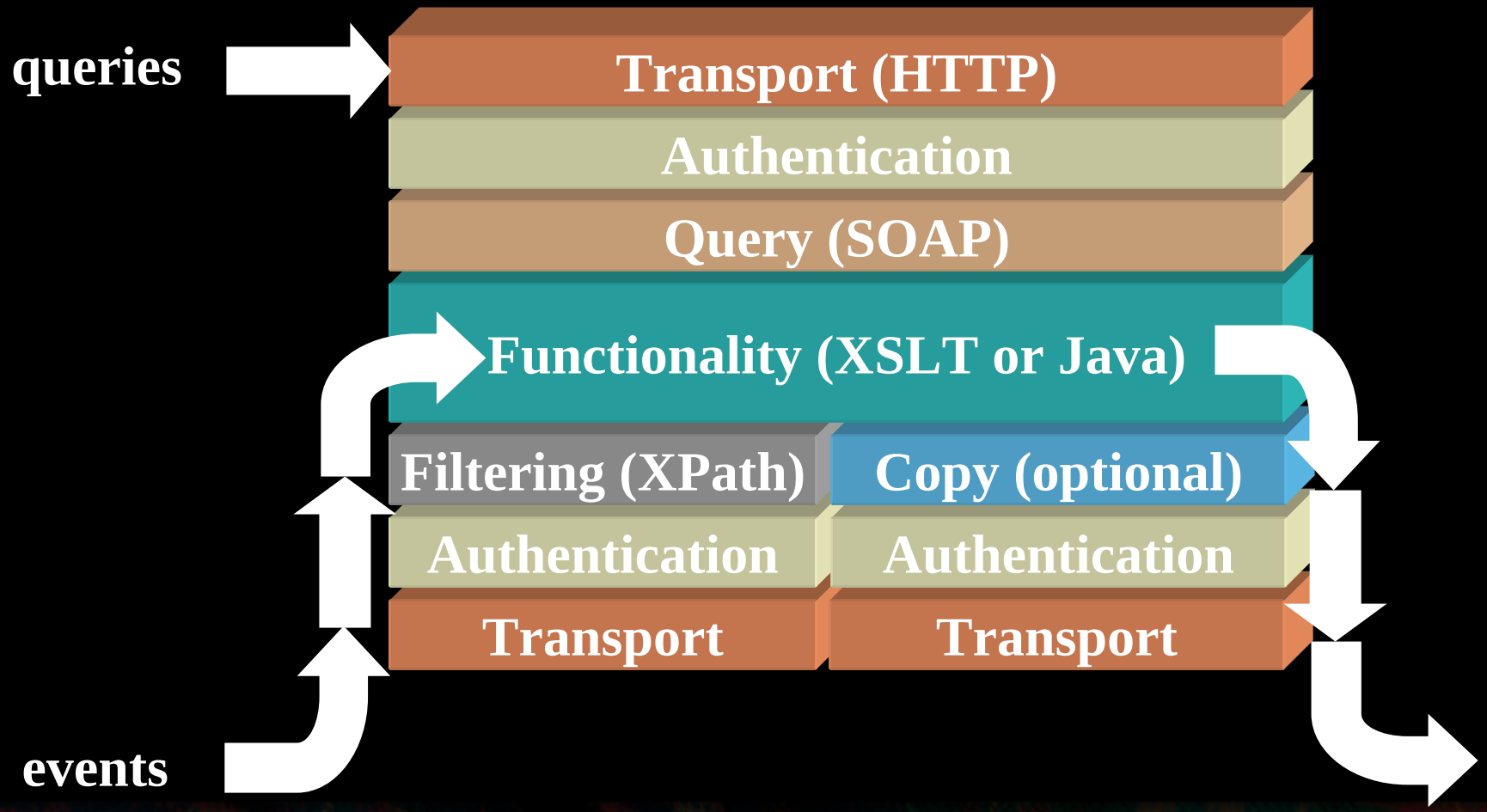
Basic Agents



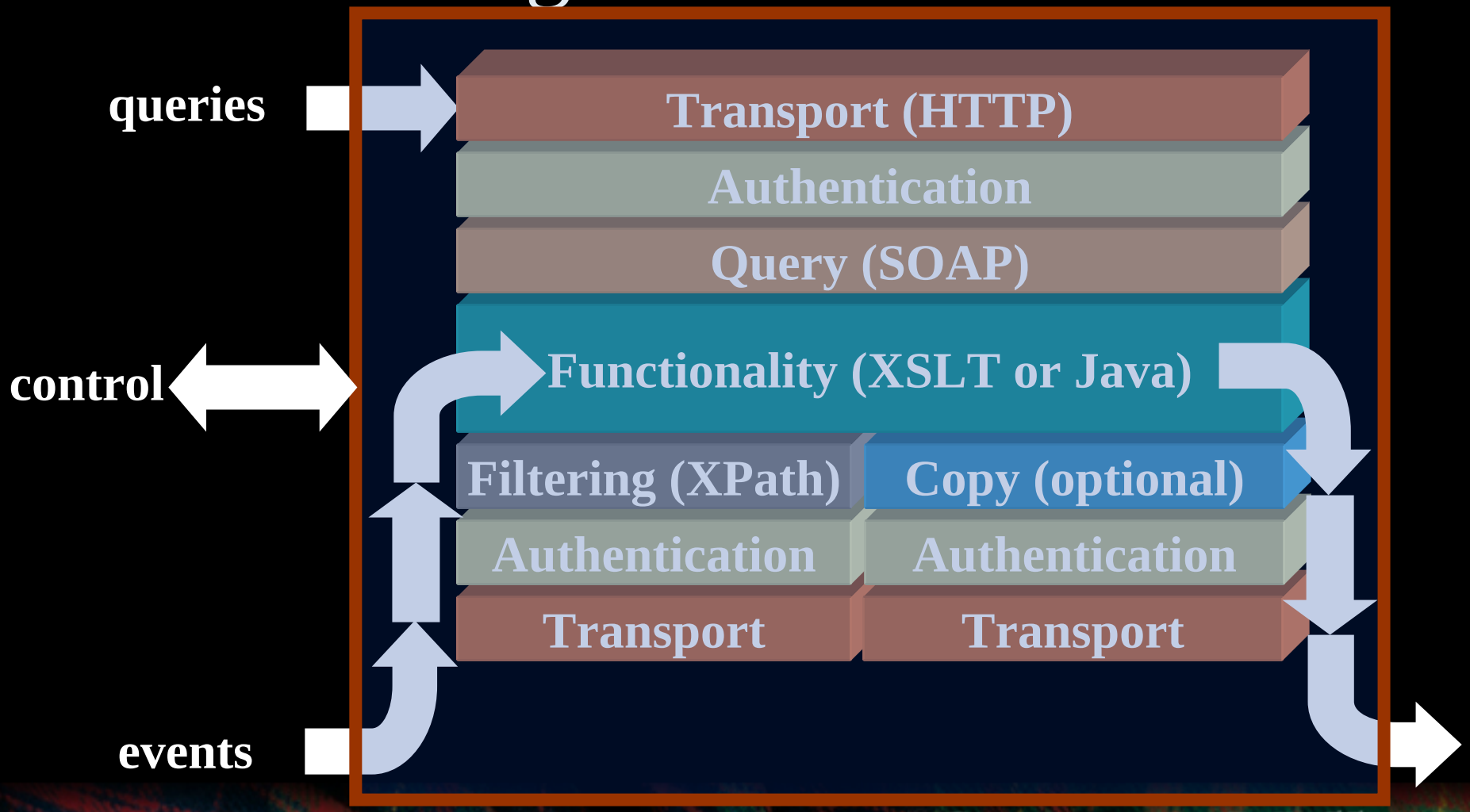
Basic Agents + Query



Storage Agents



Agent Control



Base Agent Types

- Normalization: rapidly put external events into backplane via a raw CER. Small footprint, can be ported to embedded systems.
- Transformation: convert raw CERs into cooked (parsed into XML) and/or manipulate CERs
- Anonymization: anonymize specific fields of the CER
- Application: take out-of-band action
- Analysis: inject analysis CERs into backplane based on observed events
- Display: act and a filter/preprocessor for display consoles

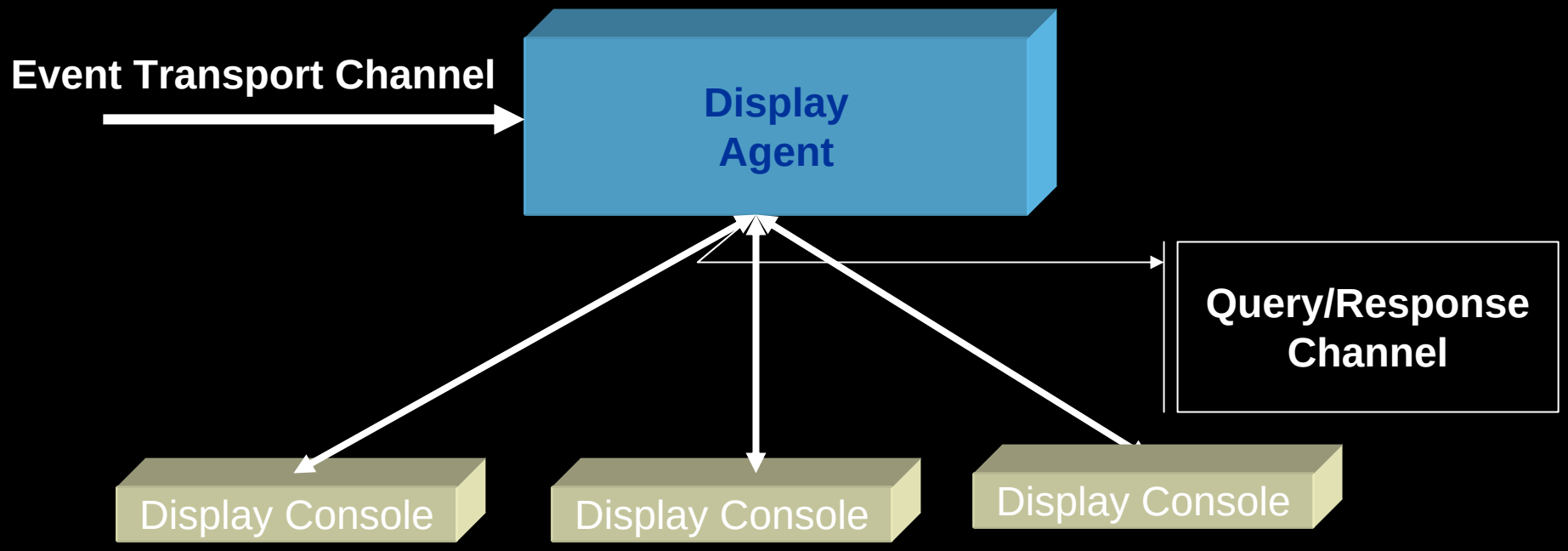
Storage Agent Types

- Archive: repository of events indexed on the base correlation structure of their CER
- Database: repository of events indexed on a specific schema (can be very granular)
- Directory: provide a event location service
  - Where do I find this type of event?
  - What is the granularity of it?

Control Agent Types

- Agent-manager: operate and manage base and storage agents on each host
- Backplane-manager: operate and manage the host-configuration agents to build and operate a specific backplane topology

Display Agent Architecture



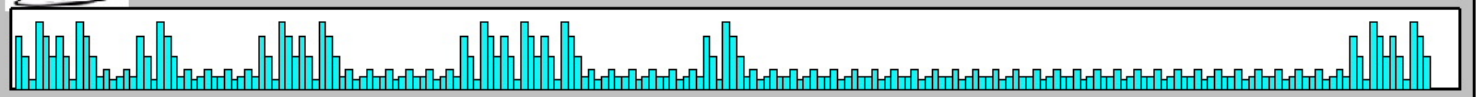
Display Agent - Forensic

Input sources: ☐ RT-Agent:_____ ☐ DB/Archive-Agent:_____ ☐ File:_____ **Authentication:** User:_____ Password:_____

Filters: EventInfoType EventCorrelationDescriptor

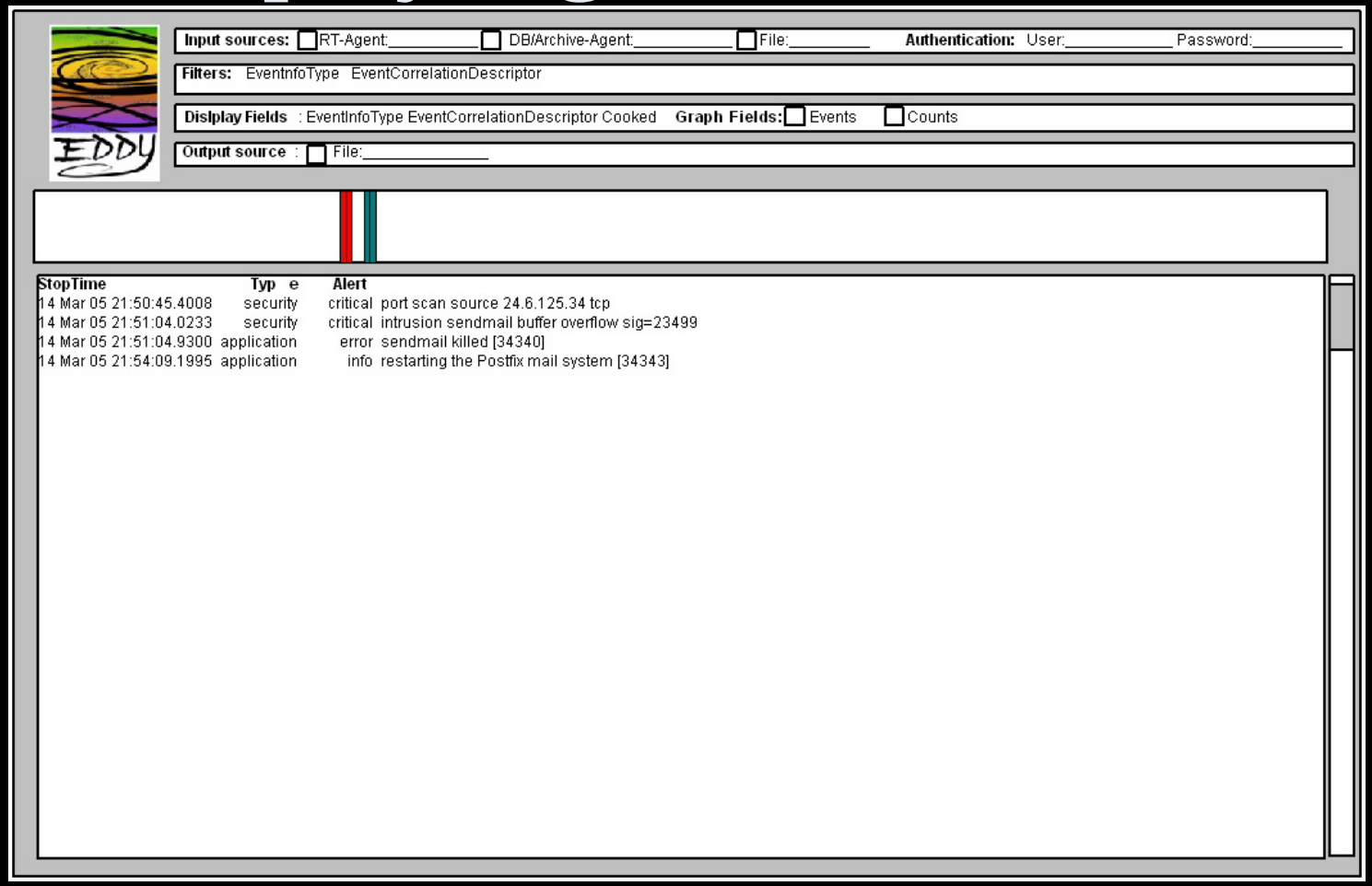
Dislplay Fields : EventInfoType EventCorrelationDescriptor Cooked **Graph Fields:** ☐ Events ☐ Counts

Output source : ☐ File:_____



EndTime	Proto	SrcAddr	SrcPort	DstAddr	SrcPkts	DstPkts	SrcBytes	DstBytes
14 Mar 05 21:51:00.4264	tcp	24.6.125.34	42964	209.195.187.23.22	20	18	3254	3443
14 Mar 05 21:51:00.5423	tcp	67.161.24.241	9902	209.195.187.23.22	21	17	3328	3377
14 Mar 05 21:50:59.9178	udp	10.149.224.1	67	255.255.255.255.68	1	0	356	0
14 Mar 05 21:51:02.4265	tcp	24.6.125.34	42964	209.195.187.23.22	2	3	132	210
14 Mar 05 21:51:02.6239	tcp	67.161.24.241	9902	209.195.187.23.22	1	1	66	66
14 Mar 05 21:51:14.2649	tcp	24.6.125.34	1692	207.46.107.142.1863	2	1	113	62
14 Mar 05 21:51:23.8084	tcp	24.6.125.34	4962	204.127.198.10.110	8	9	486	592
14 Mar 05 21:51:26.1465	udp	10.149.224.1	67	255.255.255.255.68	1	0	353	0
14 Mar 05 21:51:28.0963	udp	10.149.224.1	67	255.255.255.255.68	1	0	354	0
14 Mar 05 21:51:28.1294	udp	10.149.224.1	67	255.255.255.255.68	1	0	354	0
14 Mar 05 21:51:28.9090	udp	10.149.224.1	67	255.255.255.255.68	1	0	353	0
14 Mar 05 21:51:29.4163	tcp	64.12.24.108	5190	24.6.125.34.1446	1	1	54	54
14 Mar 05 21:51:27.9566	udp	10.149.224.1	67	255.255.255.255.68	1	0	353	0
14 Mar 05 21:51:30.7963	udp	10.149.224.1	67	255.255.255.255.68	1	0	353	0
14 Mar 05 21:51:31.9225	tcp	64.12.165.109	5190	24.6.125.34.1456	1	1	54	54
14 Mar 05 21:51:32.9819	udp	10.149.224.1	67	255.255.255.255.68	1	0	342	0
14 Mar 05 21:51:35.9002	udp	10.149.224.1	67	67.161.7.36.68	2	0	716	0

Display Agent - Forensic



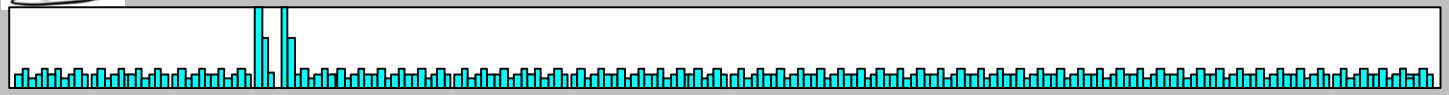
Display Agent - Forensic

Inputsources: T-Agent:_____ B/Archive-Agent:_____ e:_____ **Authentication:** User:_____ Password:_____

Filters: EventInfoTypeEventCorrelationDescriptor

DislplayFields: EventInfoTypeEventCorrelationDescriptorCookie **GraphFields:** Events Counts

Output source: File:_____



StopTime	Type	Alert									
14 Mar 05 21:51:00.4264	network	info	tcp	24.6.125.34	42964	209.195.187.23.22	1	1	74	123
14 Mar 05 21:51:01.2643	network	info	tcp	24.6.125.34	42964	209.195.187.23.23	1	1	74	0
14 Mar 05 21:51:02.3263	network	info	tcp	24.6.125.34	42964	209.195.187.23.24	1	1	74	0
14 Mar 05 21:51:03.4762	network	info	tcp	24.6.125.34	42964	209.195.187.23.25	1	1	74	54
14 Mar 05 21:51:03.6223	network	info	tcp	24.6.125.34	42964	209.195.187.23.25	64	57	30321	2344
14 Mar 05 21:51:03.8128	network	info	tcp	24.6.125.34	42964	209.195.187.23.25	17	15	9827	1023
14 Mar 05 21:51:03.9239	network	info	tcp	24.6.125.34	42964	209.195.187.23.25	1	1	63	63
14 Mar 05 21:51:04.2234	network	info	tcp	24.6.125.34	42964	209.195.187.23.25	67	63	34853	3587
14 Mar 05 21:51:04.5983	network	info	tcp	24.6.125.34	42964	209.195.187.23.25	15	13	7633	1933
14 Mar 05 21:51:04.7263	network	info	tcp	24.6.125.34	42964	209.195.187.23.26	1	1	74	54
14 Mar 05 21:51:05.2098	network	info	tcp	24.6.125.34	42964	209.195.187.23.27	1	1	74	54
14 Mar 05 21:51:06.7760	network	info	tcp	24.6.125.34	42964	209.195.187.23.28	1	1	74	54
14 Mar 05 21:51:07.3622	network	info	tcp	24.6.125.34	42964	209.195.187.23.29	1	1	74	54
14 Mar 05 21:51:08.6945	network	info	tcp	24.6.125.34	42964	209.195.187.23.30	1	1	74	54
14 Mar 05 21:51:09.4876	network	info	tcp	24.6.125.34	42964	209.195.187.23.31	1	1	74	54
14 Mar 05 21:51:10.2826	network	info	tcp	24.6.125.34	42964	209.195.187.23.32	1	1	74	54
14 Mar 05 21:51:11.1283	network	info	tcp	24.6.125.34	42964	209.195.187.23.33	1	1	74	54
14 Mar 05 21:51:12.9822	network	info	tcp	24.6.125.34	42964	209.195.187.23.34	1	1	74	54
14 Mar 05 21:51:13.3982	network	info	tcp	24.6.125.34	42964	209.195.187.23.35	1	1	74	54
14 Mar 05 21:51:14.2798	network	info	tcp	24.6.125.34	42964	209.195.187.23.36	1	1	74	54
14 Mar 05 21:51:15.5093	network	info	tcp	24.6.125.34	42964	209.195.187.23.37	1	1	74	54
14 Mar 05 21:51:16.8733	network	info	tcp	24.6.125.34	42964	209.195.187.23.38	1	1	74	54
14 Mar 05 21:51:17.3983	network	info	tcp	24.6.125.34	42964	209.195.187.23.39	1	1	74	54
14 Mar 05 21:51:18.6093	network	info	tcp	24.6.125.34	42964	209.195.187.23.40	1	1	74	54
14 Mar 05 21:51:19.5983	network	info	tcp	24.6.125.34	42964	209.195.187.23.41	1	1	74	54
14 Mar 05 21:51:20.8092	network	info	tcp	24.6.125.34	42964	209.195.187.23.42	1	1	74	54
14 Mar 05 21:51:21.4998	network	info	tcp	24.6.125.34	42964	209.195.187.23.43	1	1	74	54
14 Mar 05 21:51:22.0233	network	info	tcp	24.6.125.34	42964	209.195.187.23.44	1	1	74	54

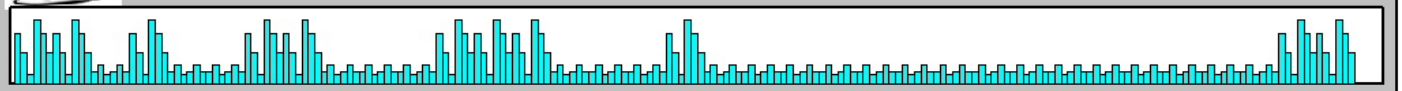
Display Agent - Specialized

Input sources: ☐ RT-Agent:_____ ☐ DB/Archive-Agent:_____ ☐ File:_____ **Authentication:** User:_____ Password:_____

Filters: EventInfoType EventCorrelationDescriptor

Dislplay Fields : EventInfoType EventCorrelationDescriptor Cooked **Graph Fields:** ☐ Events ☐ Counts

Output source : ☐ File:_____



ipAddr	iMB	oMB	iKp	oKp	flows	iMbs	oMbs	ips	ops	services(num flows)
10.7.45.202	0	75	3	61	41	0.0	2.0	11	203	-
10.7.12.27	75	0	61	3	5	2.0	0.0	202	10	-
10.7.99.240	64	1	49	20	12	1.7	0.0	161	66	-
10.7.203.92	12	39	21	30	29	0.3	1.0	70	101	-
10.7.4.53	2	40	27	27	11	0.0	1.1	88	89	-
10.7.11.101	40	2	27	27	8	1.1	0.0	89	88	52435(1),52437(1)
10.7.11.15	37	3	48	43	246	1.0	0.1	160	143	2583(19),55471(1),55473(1),+
12.7.11.45	1	26	12	20	598	0.0	0.7	40	66	-
10.7.140.24	1	25	18	21	34	0.0	0.7	61	68	3119(4),3113(4),3014(3),+
10.7.4.19	2	24	27	30	4	0.0	0.6	88	101	-
10.7.10.45	25	0	17	3	24	0.7	0.0	55	10	-
10.7.1.156	13	11	12	12	22	0.3	0.3	41	40	-
10.7.1.73	0	21	7	16	5	0.0	0.6	22	54	-
10.7.1.61	0	21	7	16	4	0.0	0.6	22	53	-
10.7.1.63	0	21	7	16	4	0.0	0.6	21	53	-
10.7.26.142	0	21	2	14	3	0.0	0.6	5	46	-
10.7.23.2	10	10	17	16	1669	0.3	0.3	55	53	9050(715),12607(20),13772(10),+
10.723.220. 6	0	16	5	11	22	0.0	0.4	15	36	-
10.7.172.19	16	0	11	6	12	0.4	0.0	36	18	4068(3)
10.7.136.105	14	0	10	5	16	0.4	0.0	33	17	-

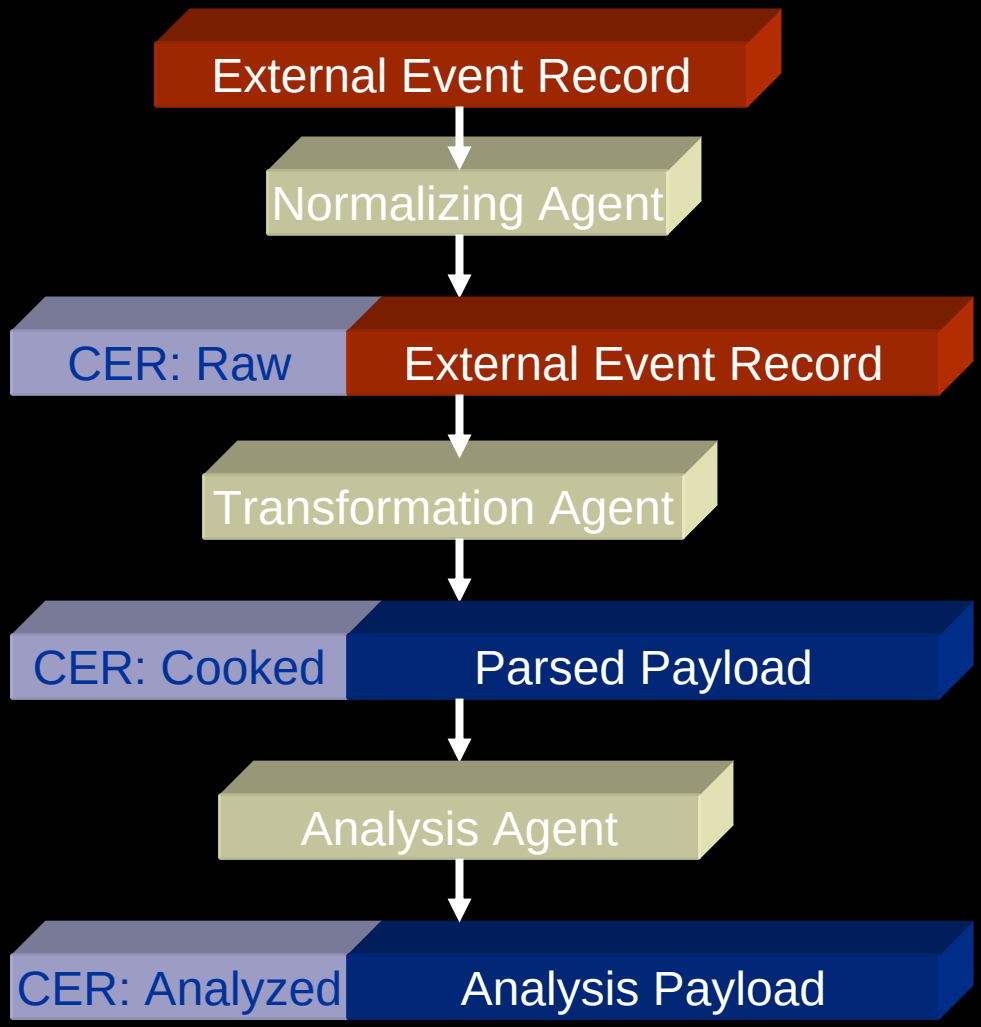
Common Agent Capabilities

- Every agent can forward, combine, split and filter event flows to other agents within the diagnostic backplane
- All transport channels (event, query, control) between agents are encrypted
- Mutual authentication based on certificates
- Initial design designed to scale to at least 5000 events/sec
- Can easily morph onto new agent types

Common Event Record (CER)

- Accommodates a wide variety of event classes easily (network, system, application, security)
- Enables high correlation between events through time, location, type and/or extensible tags
- Can be lightweight to conserve space but can be transformed onto a highly descriptive structure
- Highly flexible structure that morph to accommodate new correlation schemes

Event Progression



Common Event Record

Type Raw – no parsing of event payload

Event Descriptor	Raw Event Data

Base Information

Version - version of CER
typeID – event type (NetFlow, /var/log/messages, MS security event, etc.
eventID – identifier unique across the backplane
occurredStamp – time of the event
eventHostname – where the event occurred
eventHostAddress – address where the the event occurred
eventType – network, system, security, application or environmental
normalizerHostname – host where the normalization agent was run
normalizerAddress – address of the host where the normalization was run
warlingLevelType – emergency, alert, critical, error, warning, notice, informational, debug
correlationDescriptor – highly flexible structure to aid correlation (one for every major event type)
userTag – tag:value pairs defined at the setup of backplane to give unique meaning to events

Common Event Record

Type Cooked – raw event payload is parsed into XML

XML Structure

- Schema of raw event data
- Can be highly granular
- Defined by transformation agent

Common Event Record

Type Analyzed – high order diagnostic event

Event Descriptor	Analyzed Event Data

Diagnosis of observed events

- DiagnosisID – specific name of diagnosis
- Hypothesis – what it thought happened
- EventPointers – pointers to all the events that contributed to the hypothesis

Common Event Record Examples

- Raw
  - Network: Cisco NetFlow version 9 in payload
  - Security: Snort or MS security event
  - Application: /var/log/smtpd or MS application event
  - System: /var/log/dmesg or MS system event
  - Environmental: temperature
- Cooked
  - XML representation of raw events
  - specific fields of the XML representation of raw events
- Analyzed
  - diagnosis of DoS attack based on raw and or cooked events

Rapid Enabling of Diagnostic Applications

- Enable the forensic process
- Feeding NMS to enhance their functionality
- New visualizations to represent real-time and historical events
- Feeding research with an enormous set of data

EDDY Enabled Devices

- Workstation and servers
- Network devices (routers and switches)
- Security devices (firewalls and IDS)
- Embedded EDDY
  - Environmental devices (premises control/monitoring)
  - Transportation (automotive, etc.)
  - Robotics

Outline

- Initiative vision and direction
- Concept
- Architecture
- Campus Department/Group Involvement
- Conclusion
- Next steps

What EDDY is

- Consolidates events into a simple framework to enable correlation
- Event dissemination environment
- Diagnostic tool platform that leverages and enhances existing tools while enabling the next generation

What EDDY is not

- A system/network/application/security management platform
- The analysis engine, it enables the analysis to happen with domain expertise

Unleashing the Genie

Exposing an unprecedented wealth of diagnostic information for

- Enabling new and enhancing existing diagnostic and security applications
- Visualizing events
- Security forensics
- Researchers through the establishment of a diagnostic observatory
- Modeling new policy configurations to assess their impact on daily operations
- Analysis, validation and troubleshooting of distributed composite applications

Next Generation

- Network, application, system and security events combined
- Data represents discrete events that make up successful or failed service delivery
- True end-to-end accountability of transactions
- Auditing the behavior of an electronic transaction to establish an event profile

Seeding the Environment

- EDDY as an enabling technology provides,
  - Event dissemination and correlation infrastructure
    - Gives researchers access to event data (anonymized) on the security, application and network domains
  - A development platform for diagnostic research in the areas of
    - Applications and Middleware
    - Networking
    - Security

Outline

- Initiative vision and direction
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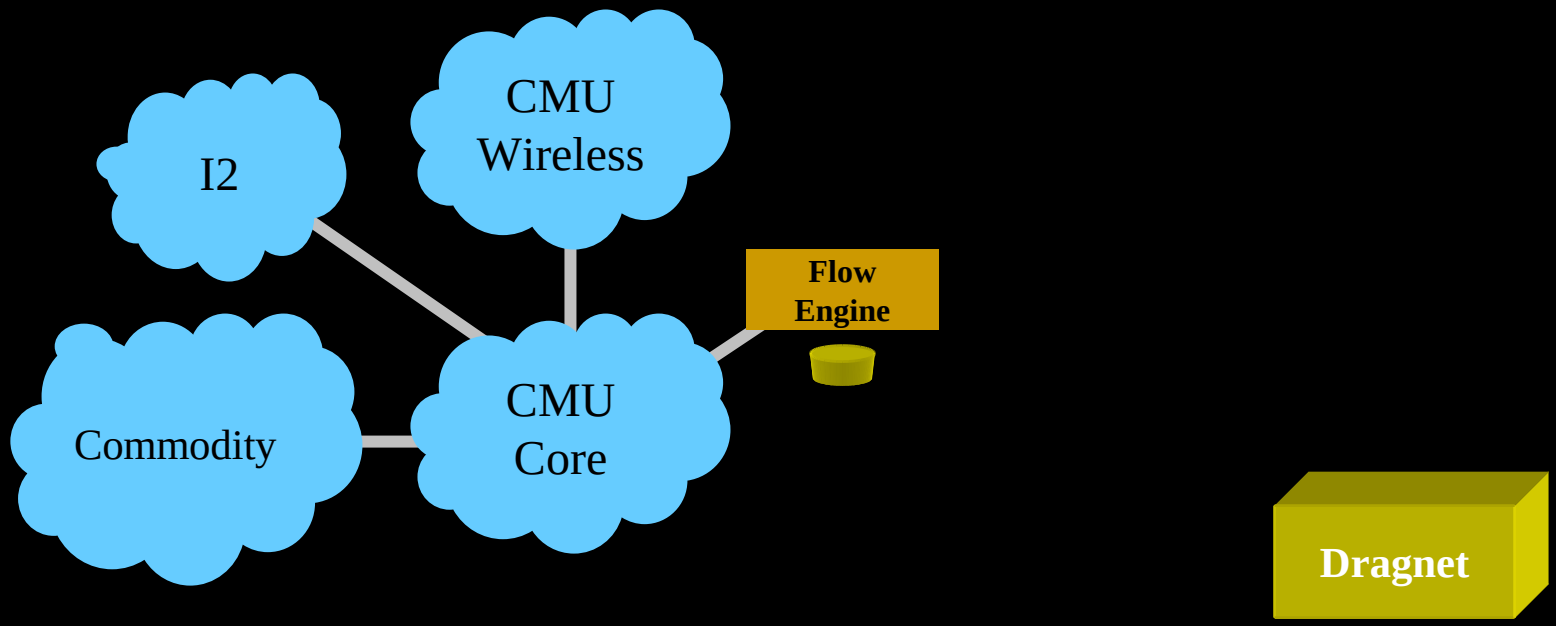
- Next steps

Enabling Campus Members

- Funding for extended research
  - A platform to discover new diagnostic application methods
  - Exposing a “petri-dish” for researchers to gain access to security, system, application, environmental and network events
- Enterprise diagnostics
  - Within CMU Computer Services
  - Other federated applications

Dragnet (use case for scale)

- Real-time security analysis using network flow records across campus core



Dragnet (use case for scale)

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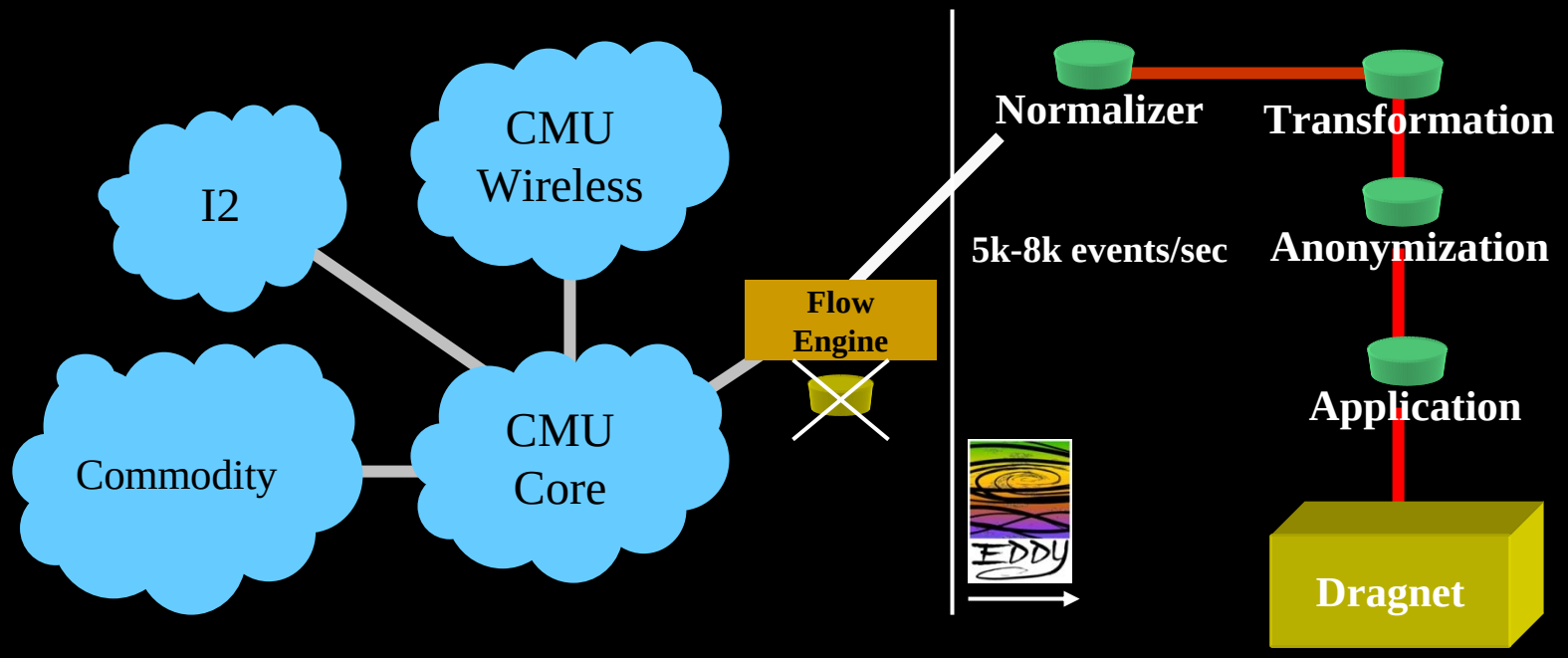

Dragnet (use case for scale)

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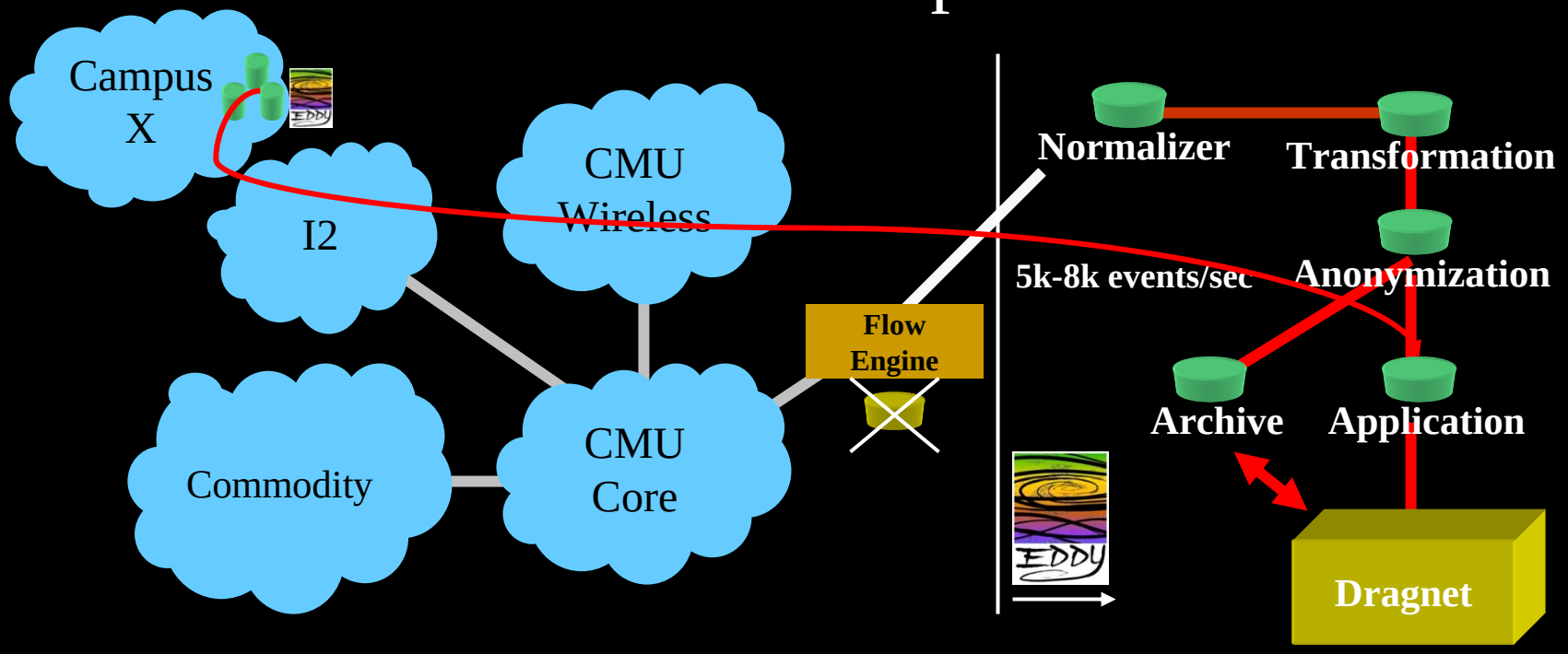
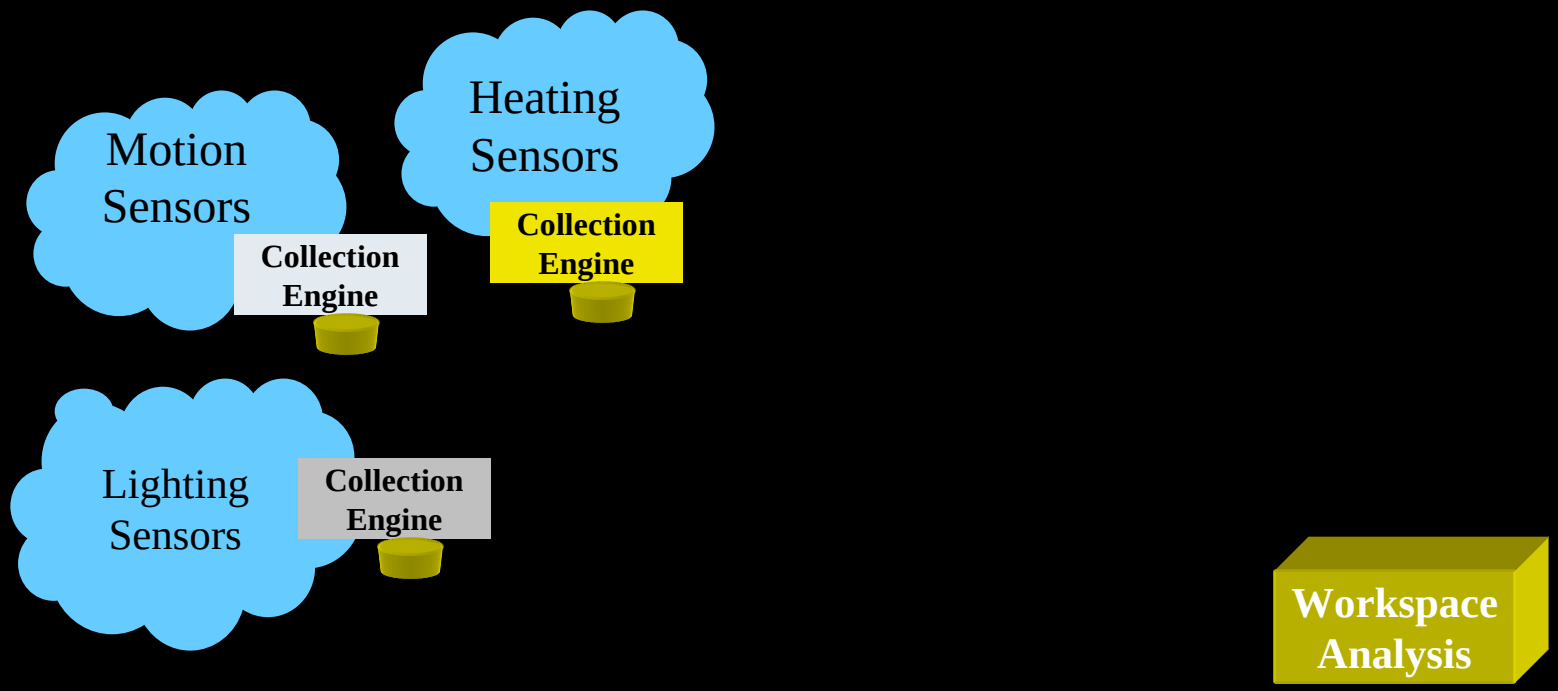


Intelligent Workplace – School of Architecture (use case for CER)

- Capturing events from all aspects of a physical environment



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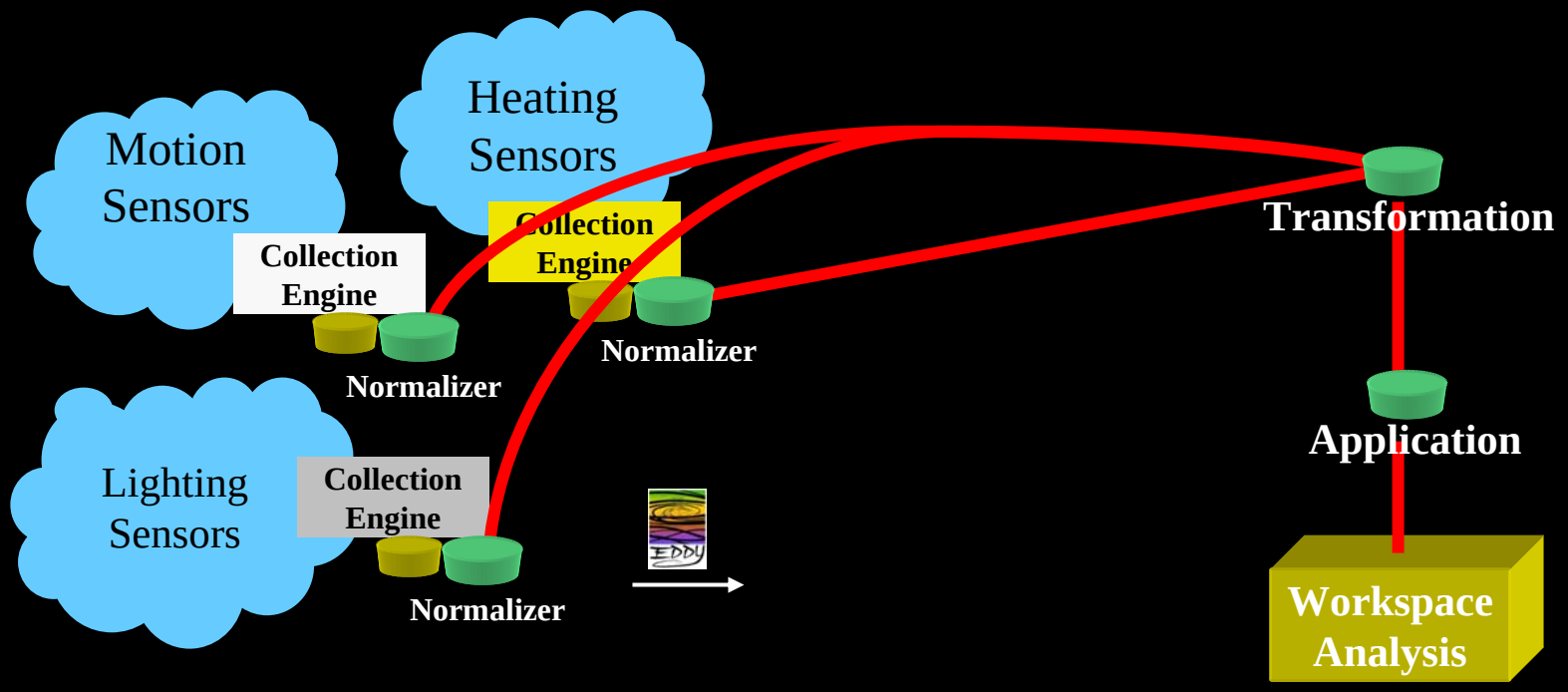

Year Two Goals

Mature the Common Event Record

- ✓ Solicit input on completeness of version 1.0
- ✓ Must be able to morph to new CER formats and providing backward compatibility
- ✓ Address scaling issues with respect to the record size and consider other data representation formats
- ✓ Include second order events such as measurement and performance
- ✓ Incorporate a mechanism for more granular correlation of events

Year Two Goals Cont.

Scale the diagnostic backplane

- Adopt a real Authz/Authn methodology
  - We use certificates at this time, but management is an issue
  - Shibboleth non-web version ready
- Provide an event anonymization
  - ✓Specific agent devoted to policy based functionality
- Transport method evolution
  - ✓Removed the dependency of SCP
  - ✓Add real-time flow capability
- Migration from Python or offload compute intensive areas
  - ✓Now Java
- Management and Configuration
  - Centralized configuration
  - Keep the configuration work on the clients hands free

Year Two Goals Cont.

Add Applications...

Domain specific

- Work with middleware application, network, system, security groups to build focused apps based on what we've learned from scenario writing process
- Discuss performance/measurement with external groups

Mature and establish a base application with GUI interface for forensics and reporting

- Reporting – feed appellations like cricket and crystal reports
- Forensics – need a client GUI interface that is ported to Linux, Mac and Windows

Year Two Goals Cont.

Add more applications...

Build simple but high value tools that extract information from the archive and not the DB

- Summaries of events
- Top event hosts
- For retrieving data that is not sent to the DB

Version 1 of the Event API

- Acquiring a real-time event flow from any node
- Simple data locator service (where can I find this data)
- Querying data repositories directly but be conscious of future capabilities where agents may mine data over multiple repositories

Status

- Development
  - Core developers driving to core release 5/05
- Campus Adopters – initial use cases
  - CS/Cylab – security research, real time flow events from commodity Internet
    - Dragnet – network flow event security analysis
  - Architecture – environmental monitoring and control
    - Environmental event data from many ultra small devices and embedded systems
  - Computing Services ISAM/Security Office
    - Consolidation of application log files, fault analysis
    - Conduit for reporting and high level event consumption

Status Cont.

- Outreach
  - Involving others in the development process
  - Expand to other use cases external to CMU
- Funding
  - Sponsored by the National Science Foundation under the NSF Middleware Initiative - Grant No. ANI-0330626
  - Expanding the effort by increasing funding to
    - Mature base technology
    - Spawn effort for diagnostic application development
    - Enable multi-subsystem correlation
    - Experiment with extending research data flow analysis into multi-campus; federating/automating some diagnostic data sharing
  - Soliciting development partners in both industry and government

Enabling other Efforts and Tools

Diagnostic assistance is provided through the system in several ways:

- Existing diagnostic tools have been or can be fitted with EDDY normalizers and translators to join into the backplane and make their data available to other applications or to specific help desk/service personnel.
- Applications can be fitted with similar EDDY normalizers to inject their error logs and diagnostic information into the Backplane.
- Existing diagnostic tools can be enriched though access to additional diagnostic data through tapping into other sources of information within the backplane.
- New diagnostic consoles can be developed and assembled from components that access and analyze the rich resources on the backplane.
- Applications can utilize diagnostic data at lower levels of the protocol stack and present better information to users about problems in access or performance.
- The diagnostic capabilities can be positioned to provide audit mechanisms as well.

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Discussion

Special thanks to the following to make the effort possible...

- Jim Gargani (CMU) – lead developer/design - core
- Kevin Miller (Duke) – design - core
- Tom Neuendorffer (CMU) – design/developer – visualization
- Walter Wong (CMU) – developer/design - core