# Power and Telecom Management Networks: Real-time Anomaly Detection and Correlation

**Simin Nadjm-Tehrani**

www.ida.liu.se/~rtslab

Department of Computer & Information Science

Linköping University, Sweden

and

University of Luxembourg

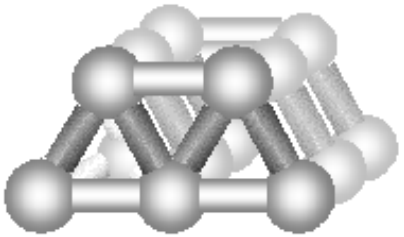
# Overview

- First EU (IST) Critical Infrastructure Project
  - Outcomes and lessons learnt

SAFEGUARD

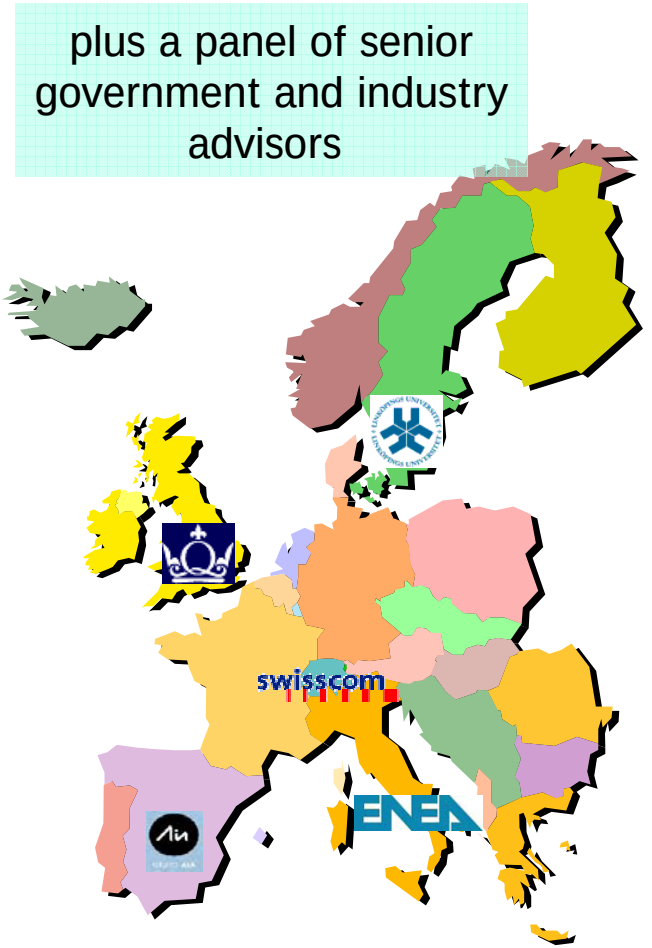
- CRIS: International Institute for Research on Critical Infrastructures

(will return to this tomorrow)



# Safeguard: 2001-2004

- Goal: to enhance survivability of Large Complex Critical Infrastructures (LCCIs)
- Electricity and telecommunications networks as practical examples
- Pre 9/11!



# Where to start?

- Power grid of today or tomorrow?
- Telecom of today or tomorrow?

# Restructuring of Power Grid

- Deregulation: organisations can enter into bilateral or multilateral power generation contracts
  - Large scale operation: from centralised to distributed control
  - Difficulty of coordination among independent service operators
- Approaching grid capacity
- New monitoring and control problems

# Telecom challenges

- Convergence of technologies
  - Everything is changing: services, business models, enabling technologies
- Internet dependability and security paramount to telecoms

# Challenges

General:

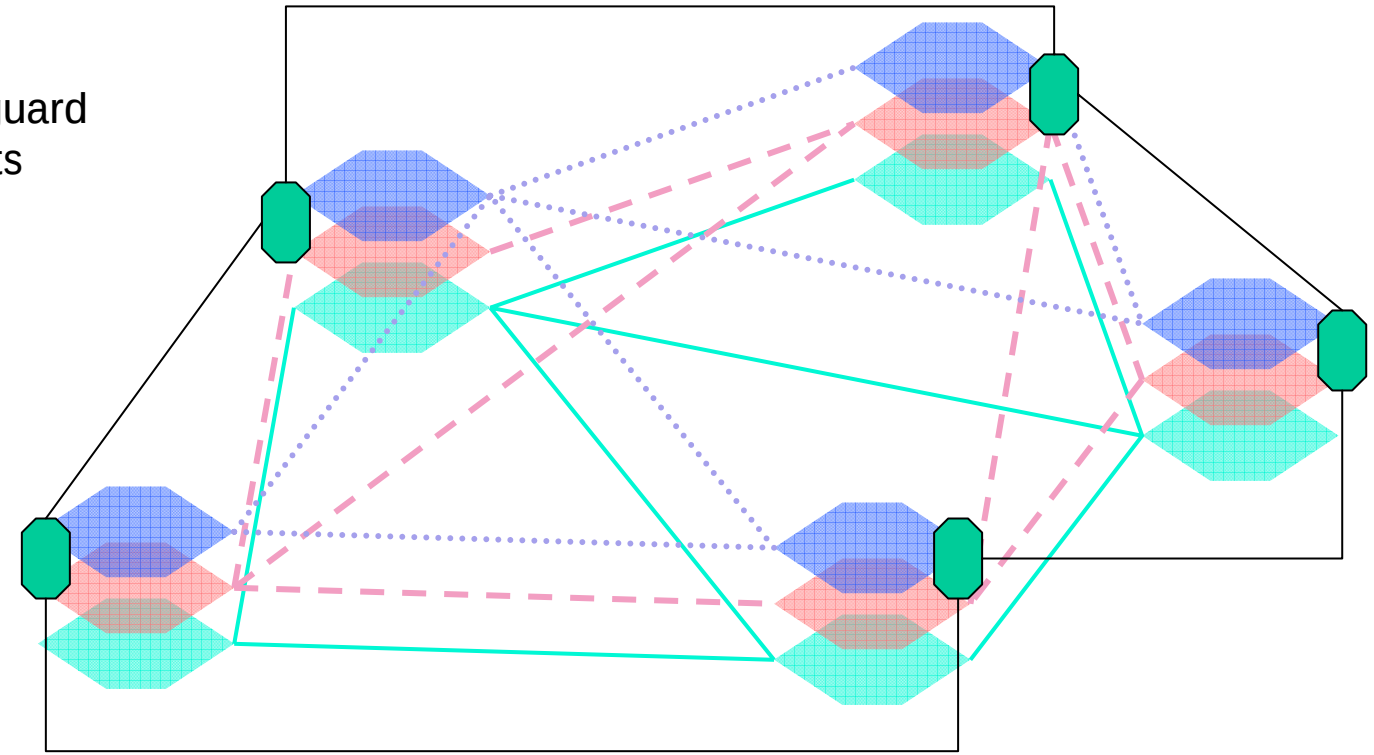
- Increase information quality for administrator
- Recognise unknown attacks
- Predict future overloads

Telecom specific:

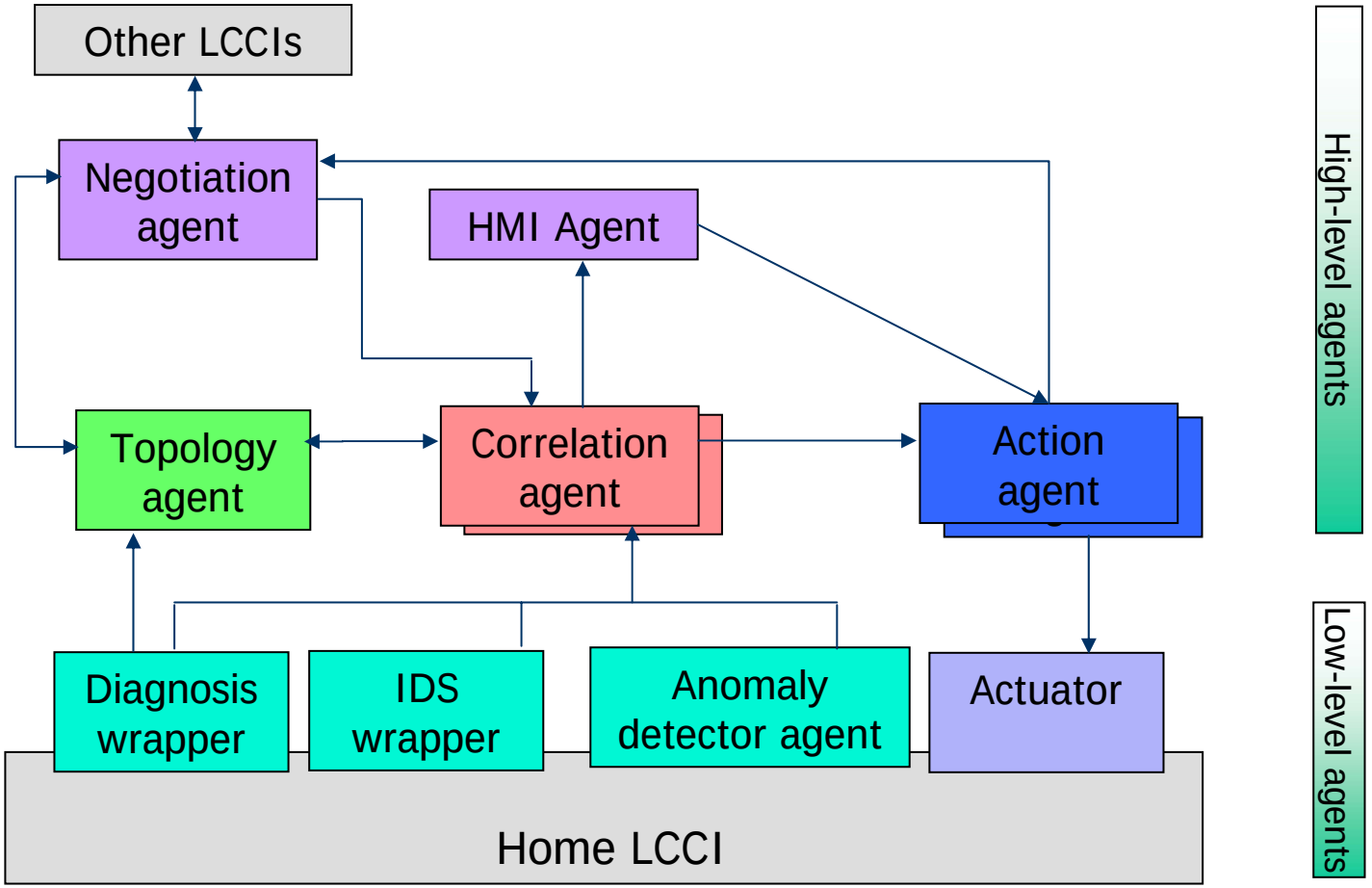
- Decrease no. of alarms
- Decrease false positives (higher availability)

# The Safeguard approach

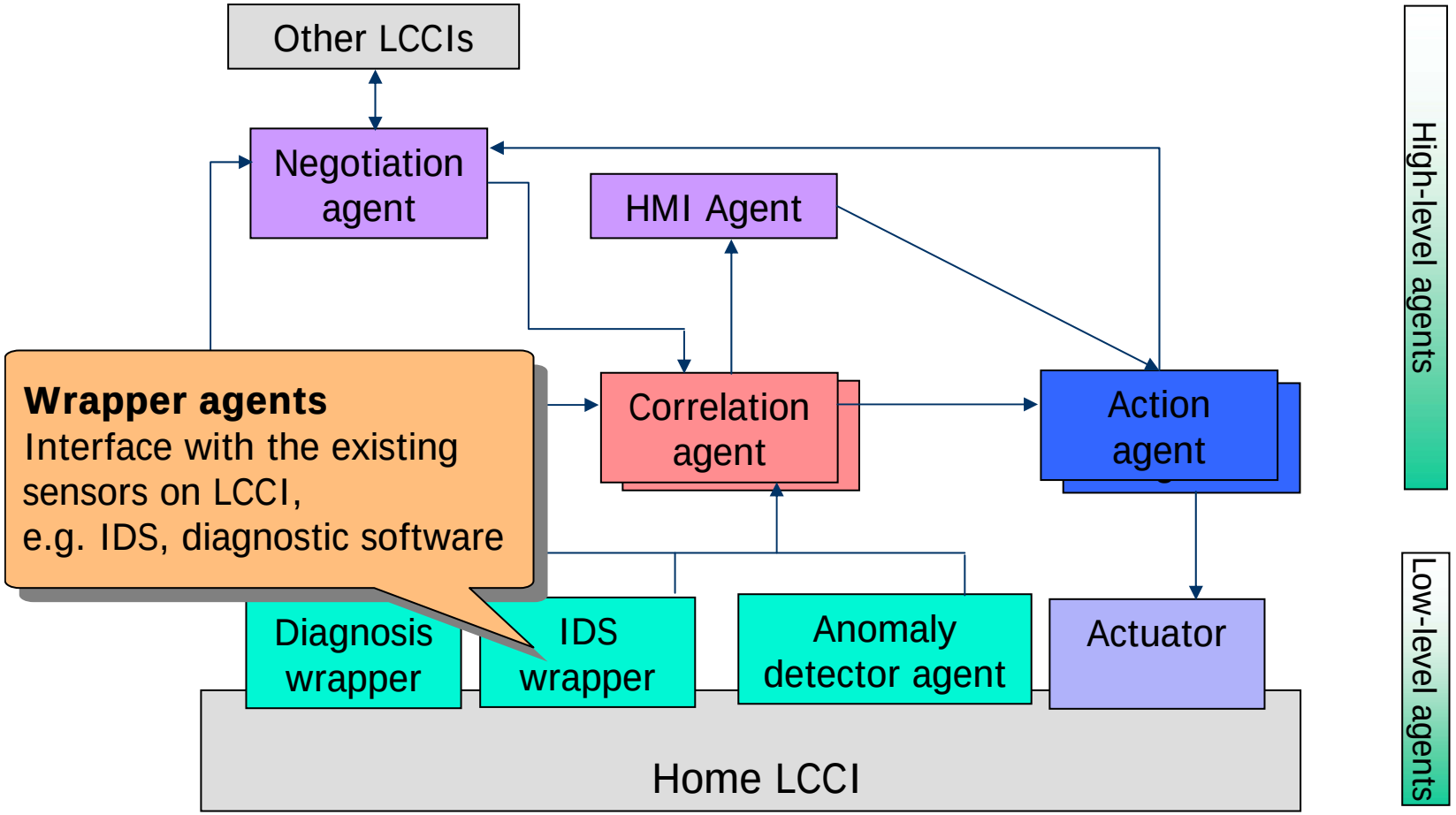
Safeguard agents



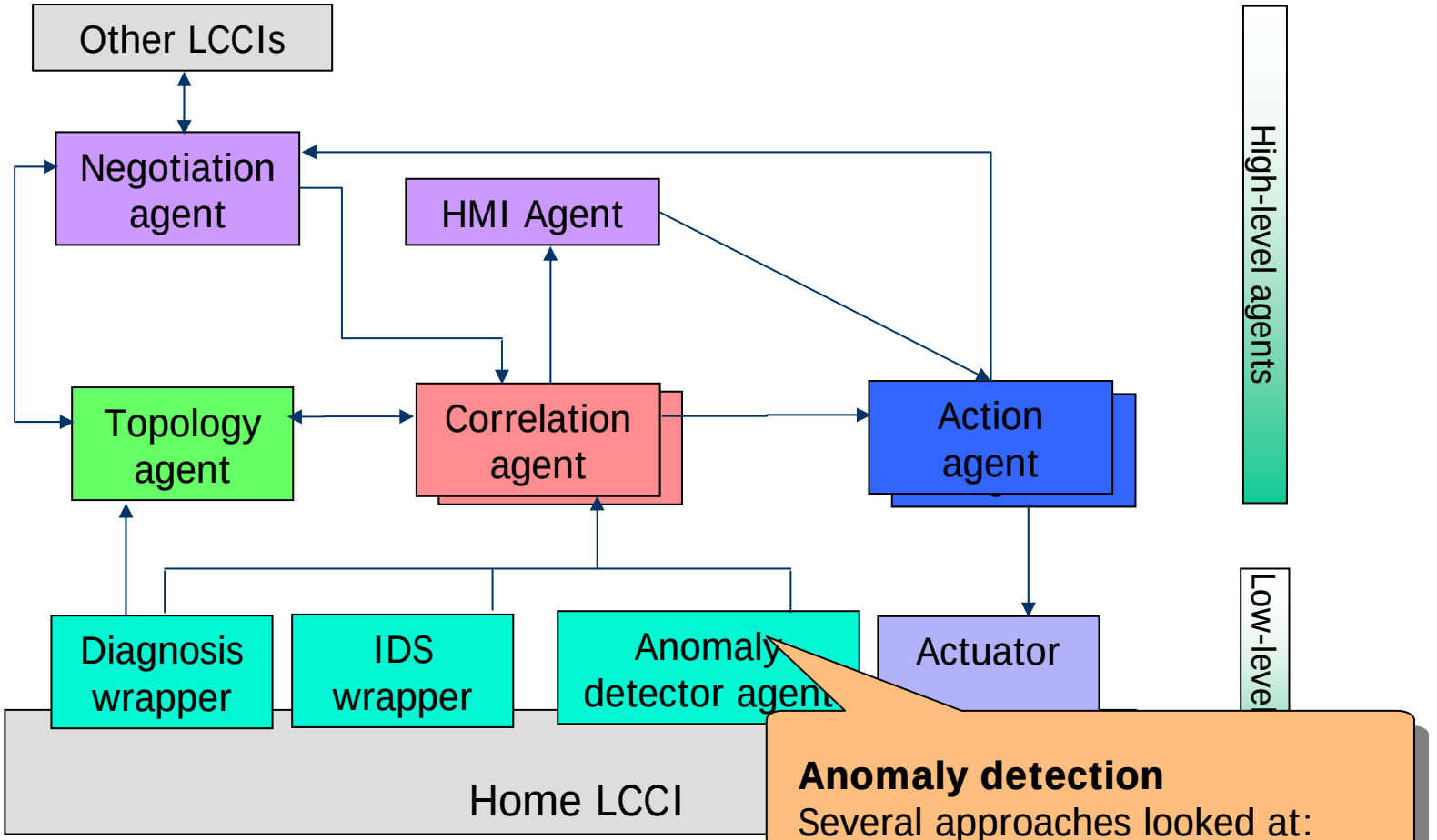
# Context: Safeguard architecture



# The Safeguard architecture

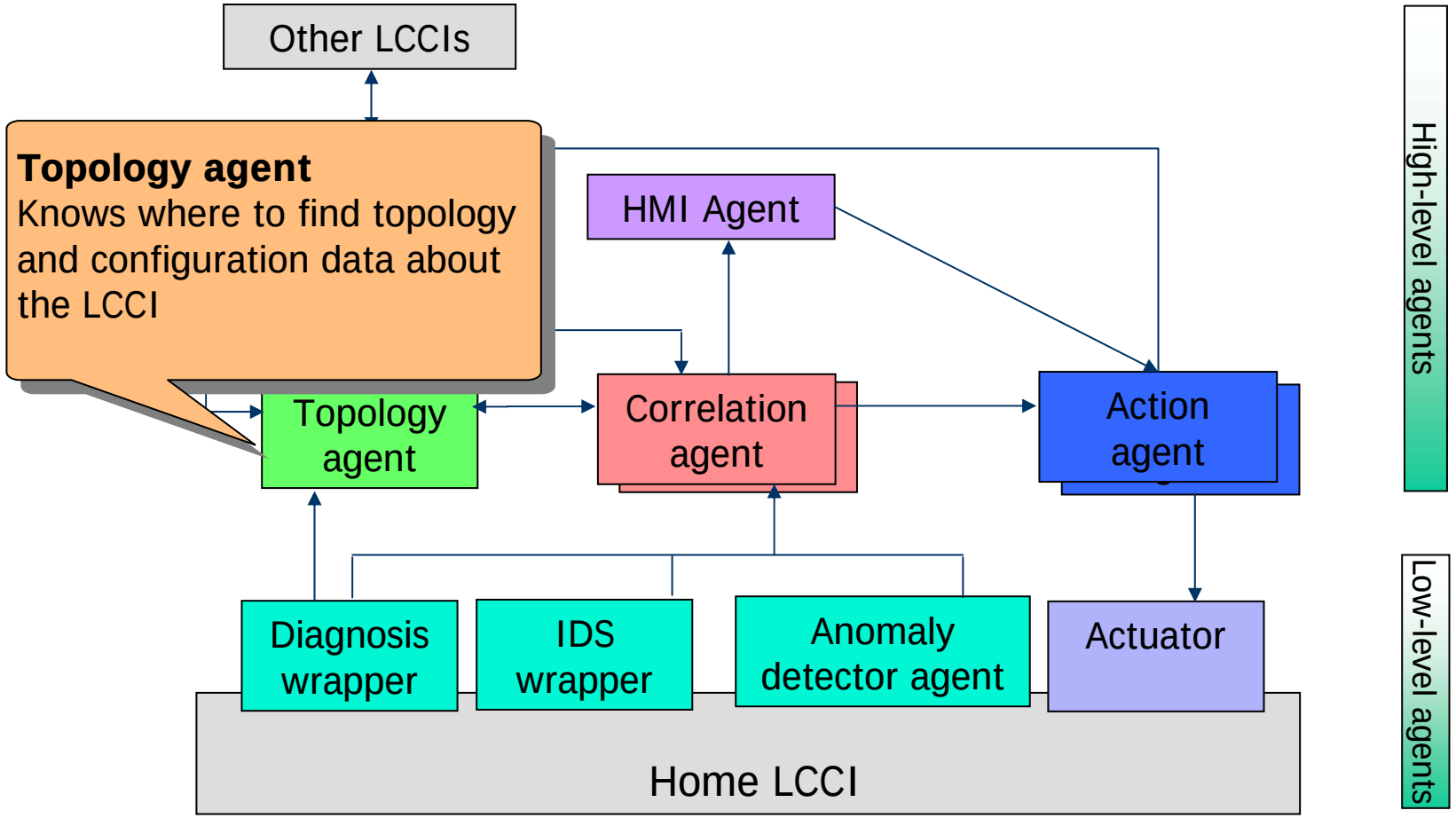


# The Safeguard architecture

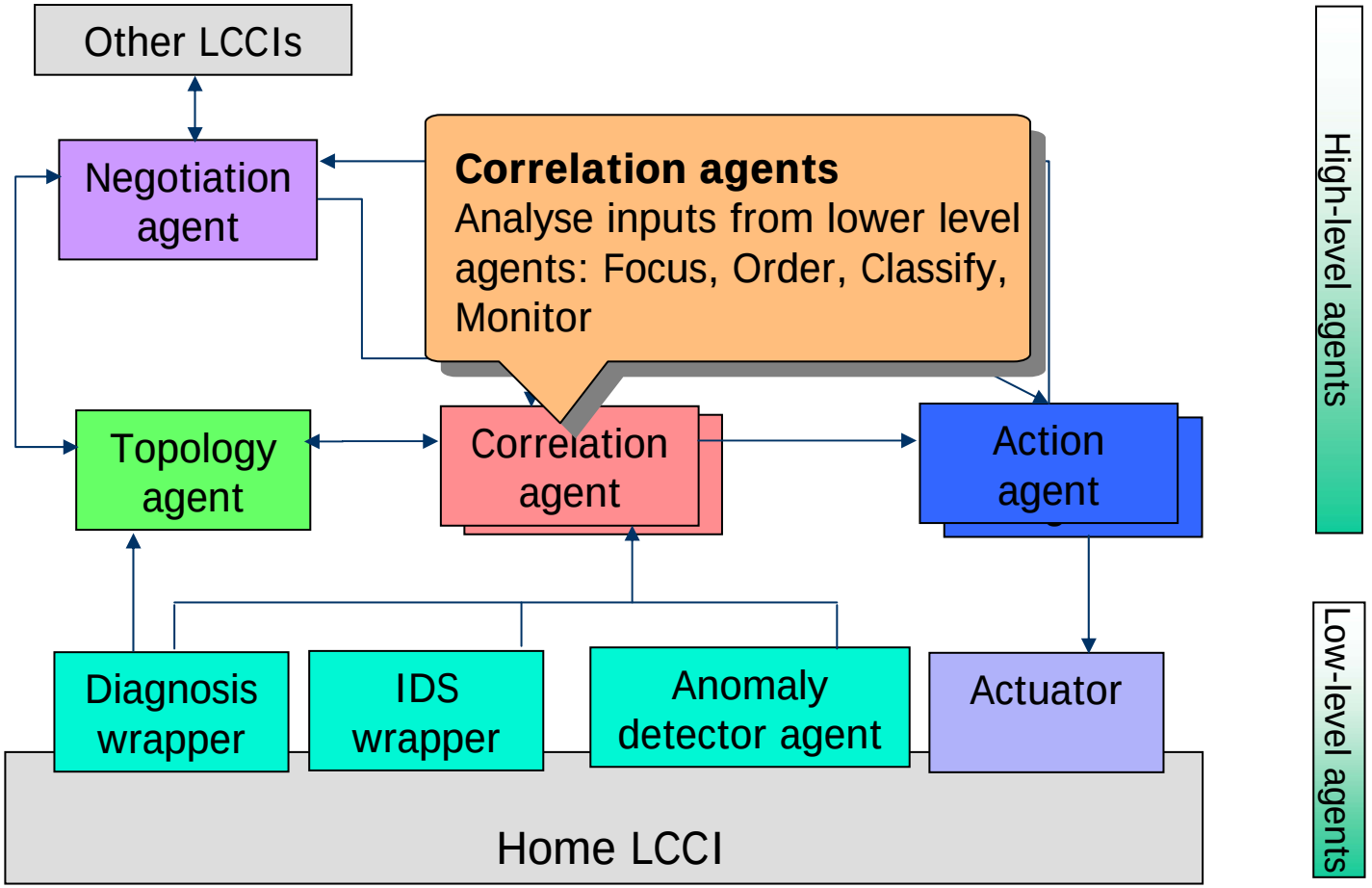



**Anomaly detection**
Several approaches looked at:
- Case Based Reasoning
- Clustering (ADWICE)
- Invariant detection

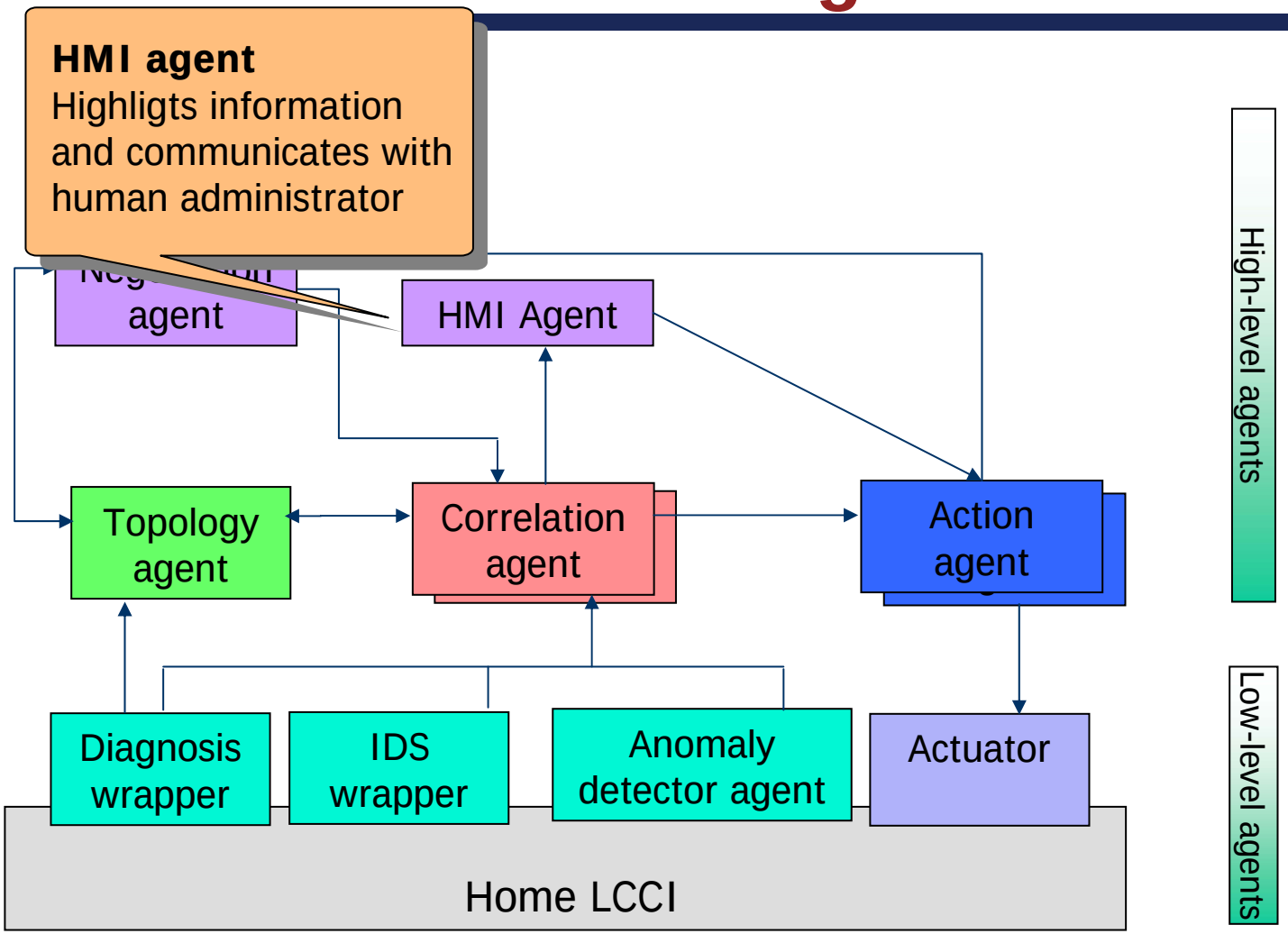
# The Safeguard architecture



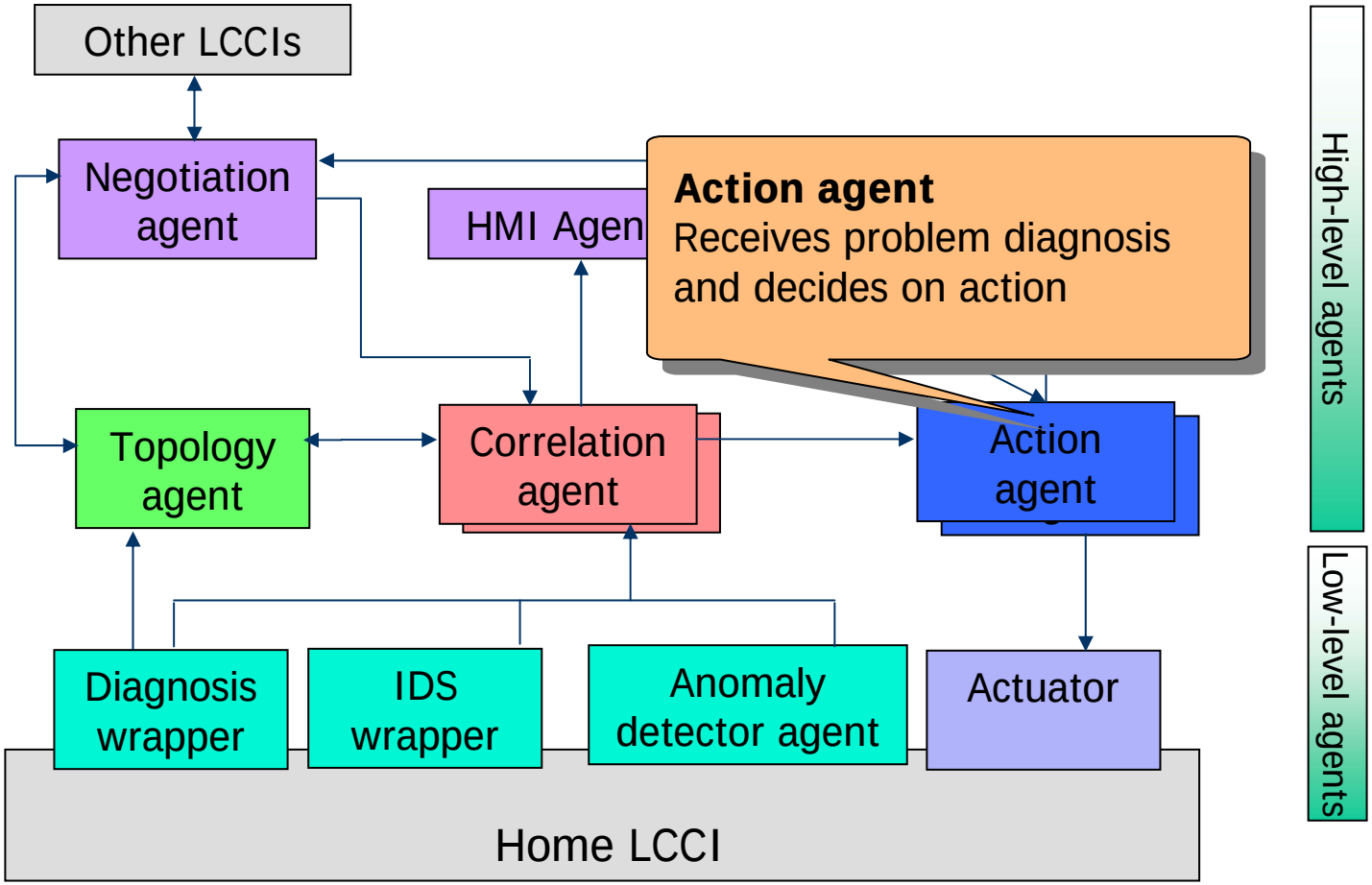
# The Safeguard architecture



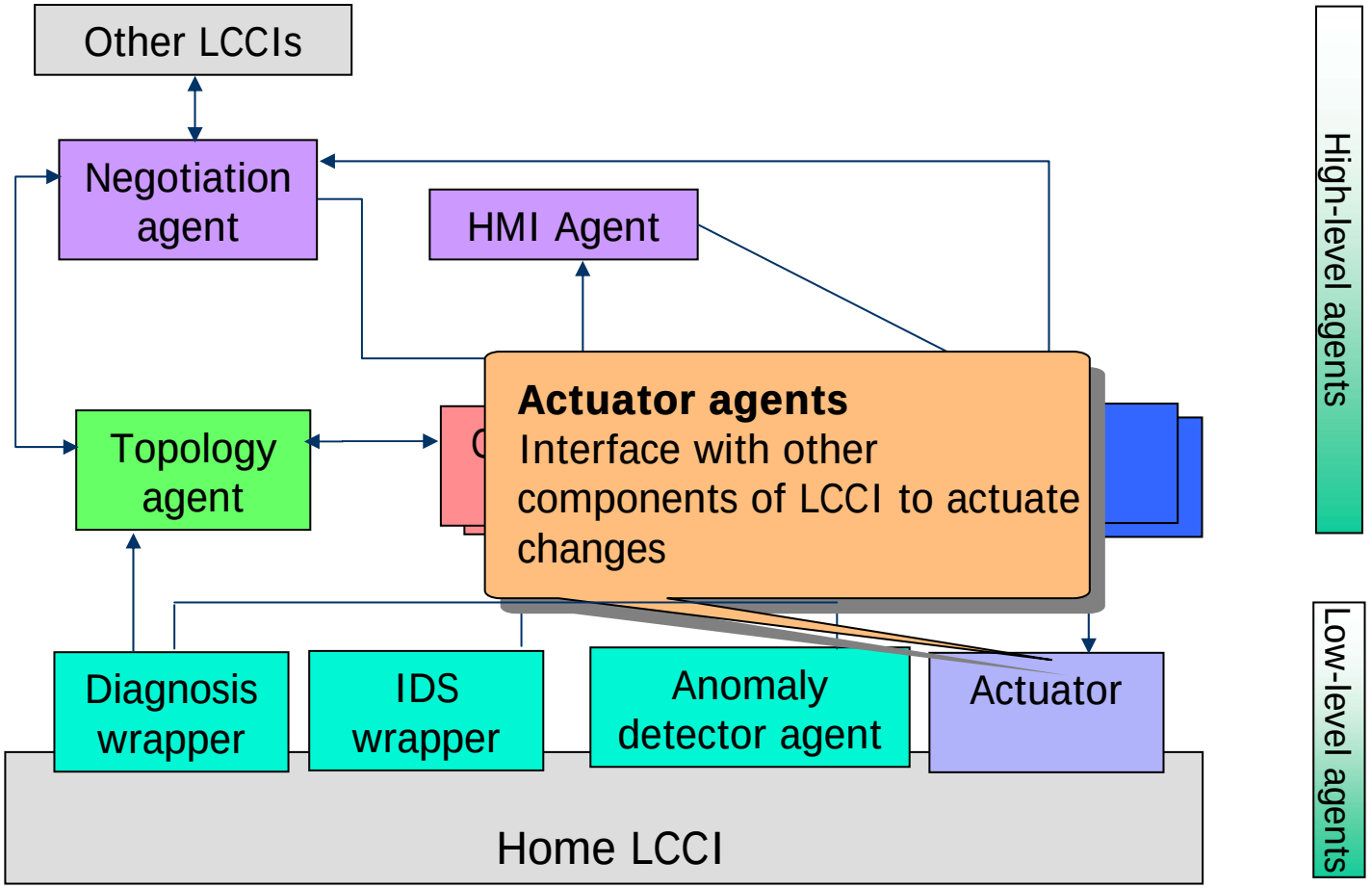
# The Safeguard architecture



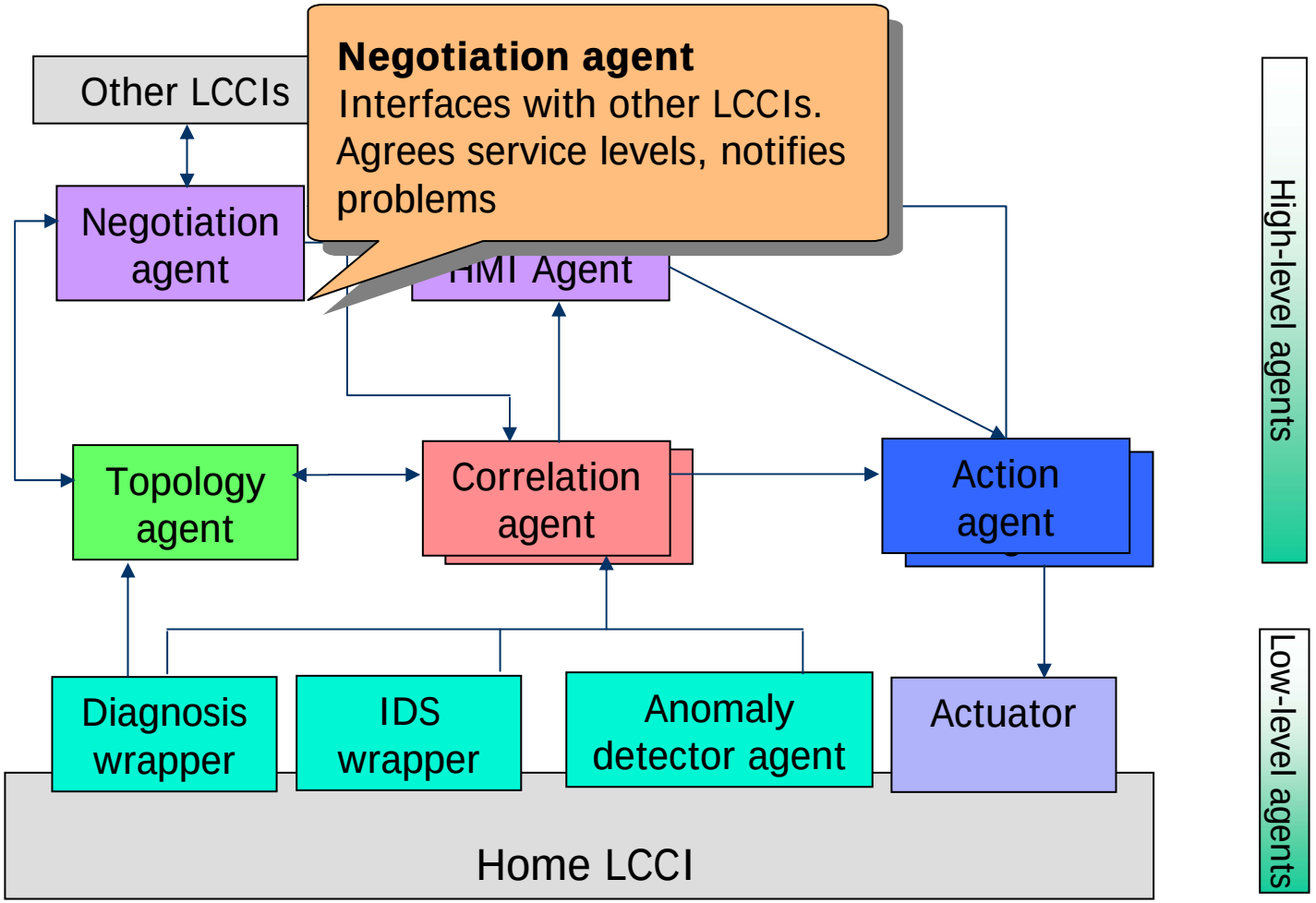
# The Safeguard architecture



# The Safeguard architecture



# The Safeguard architecture

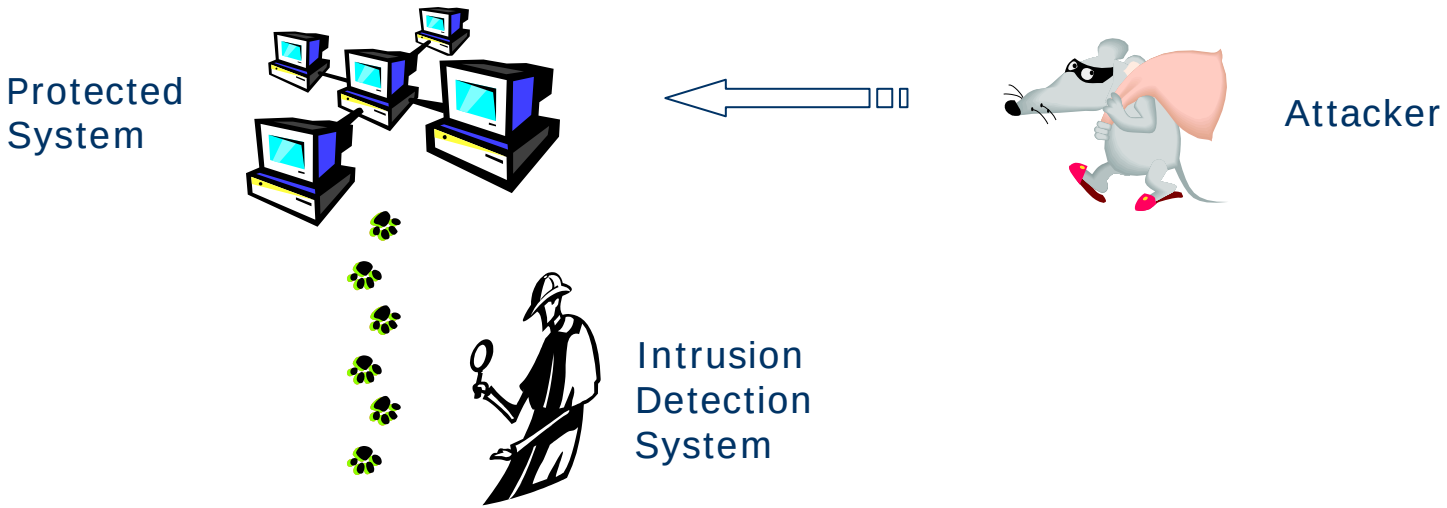


# Anomaly Detection

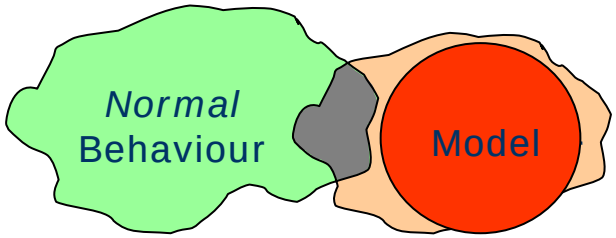
- ADWICE: Anomaly Detection With fast Incremental ClustEring
- Joint work with Kalle Burbeck

- Not a silver bullet: part of the larger Safeguard context

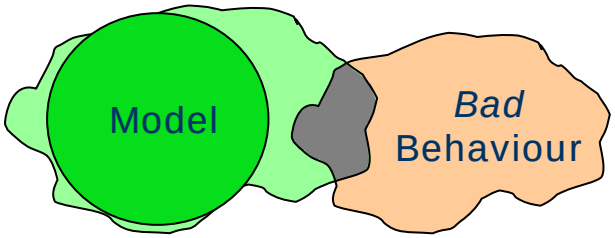
# Intrusion detection




## *Misuse Detection*

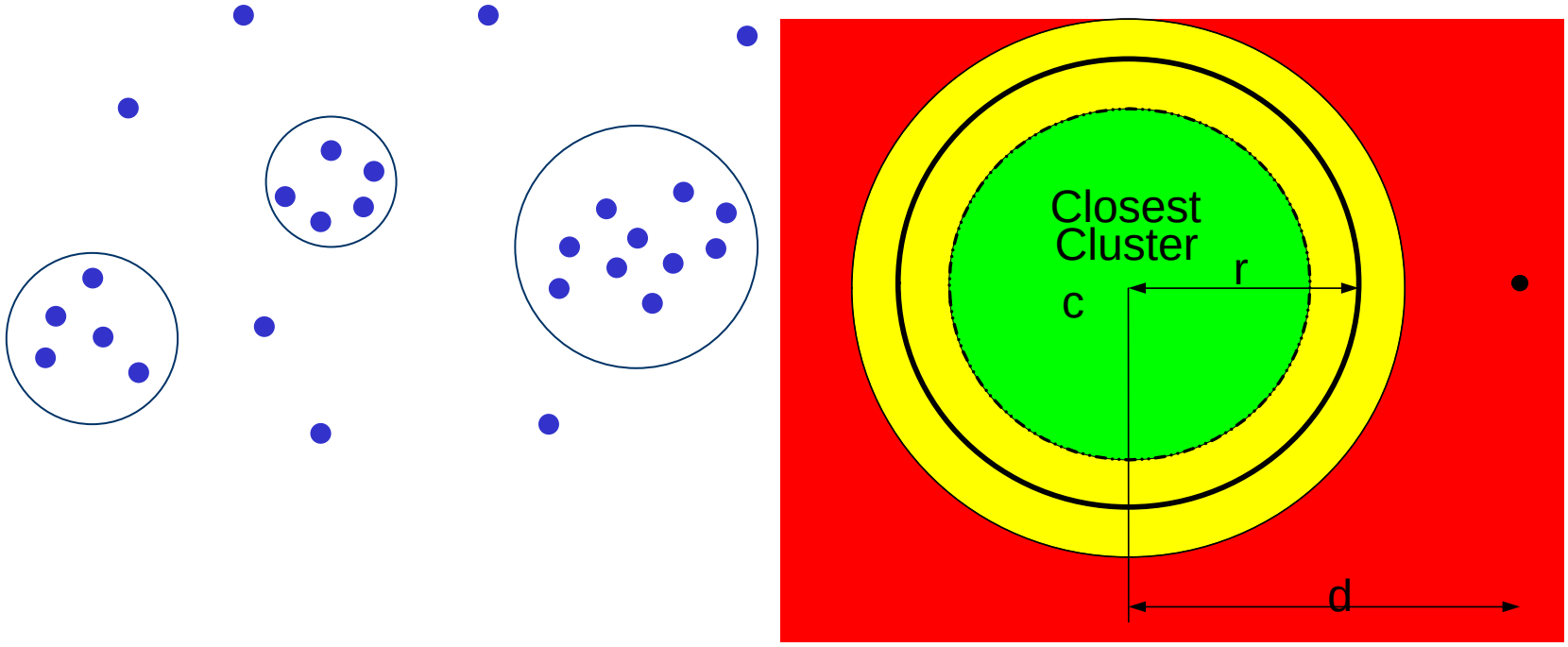



## *Anomaly Detection*



# Clustering

- ADWICE uses clusters to represent normality
- Adaptation of an existing data mining algorithm (BIRCH)

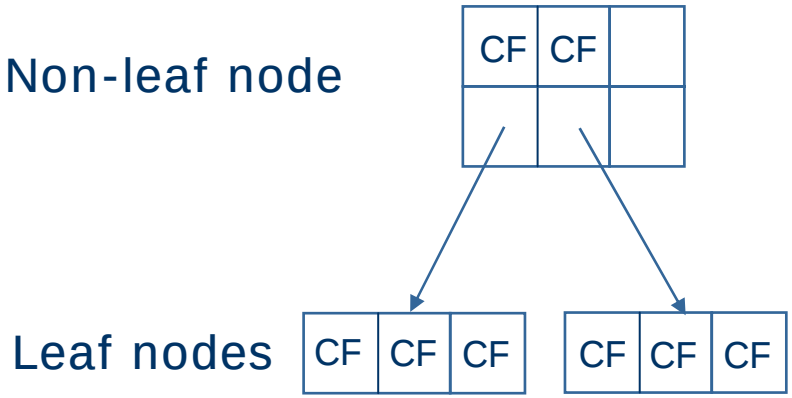


# What is a data point?

- General: A set of numeric values
  - E.g. measurements from sensors
- What about IP packets?
  - A vector of alphanumeric values in header of an IP packet
  - Transformed into vector of numeric values
  - In our tests: 41 dimensions
- Need efficient storage and search among summaries of collections of data points

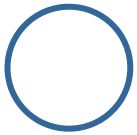
# Basic ADWICE concepts

- CF (Cluster Feature)
  - Summary of cluster
  - [No, Sum, Sum of sq]
- Index: CF Tree




- Maximal number of clusters (M)
- Threshold requirement (TR)
- Branching factor (B)

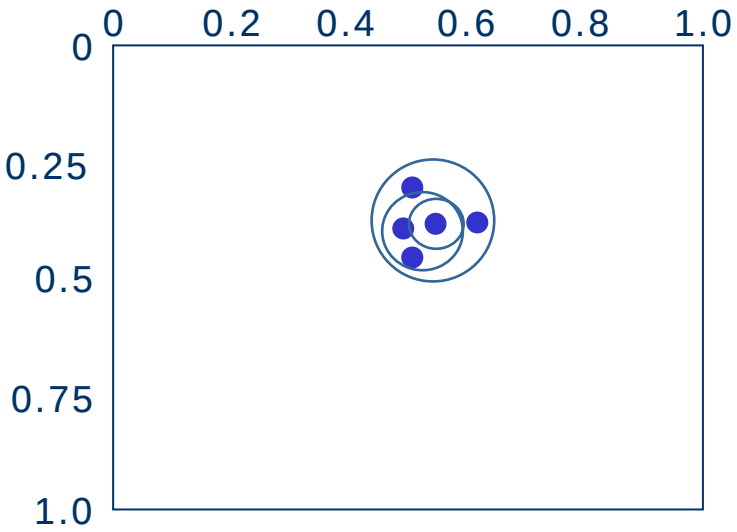
# ADWICE training

**Threshold:** 

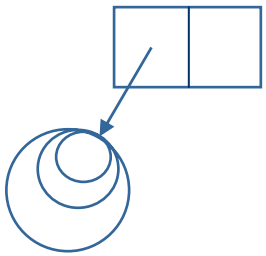
**Max Number of Clusters: 3**

**Branching factor: 2**

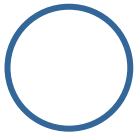
**Data Space**




**CF Tree**



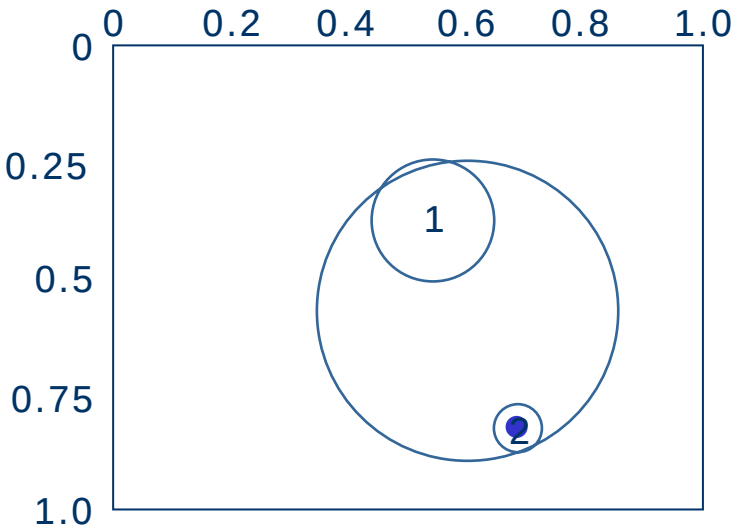
# ADWICE training

**Threshold:** 

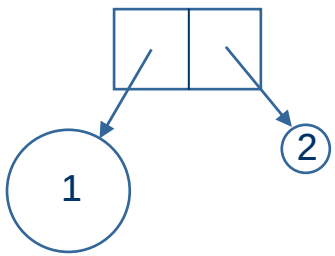
**Max Number of Clusters: 3**

**Branching factor: 2**

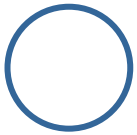
**Data Space**




**CF Tree**



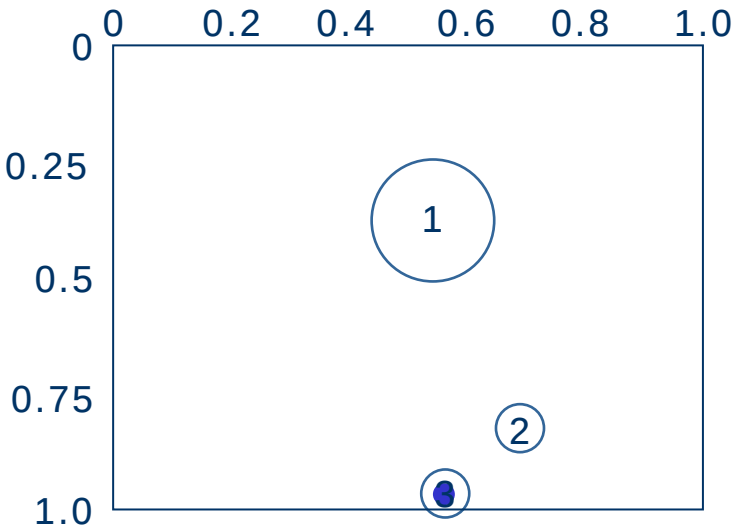
# ADWICE training

**Threshold:** 

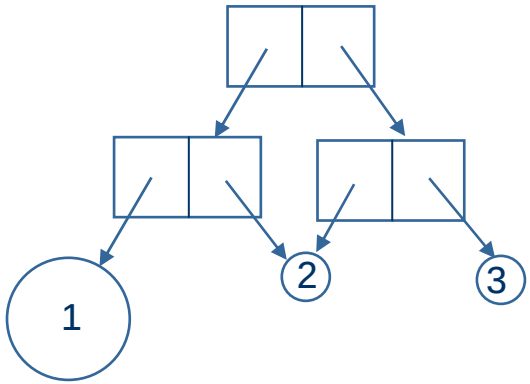
**Max Number of Clusters: 3**

**Branching factor: 2**

**Data Space**

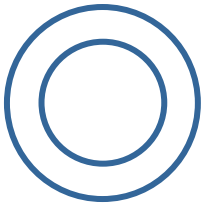



**CF Tree**



# ADWICE training

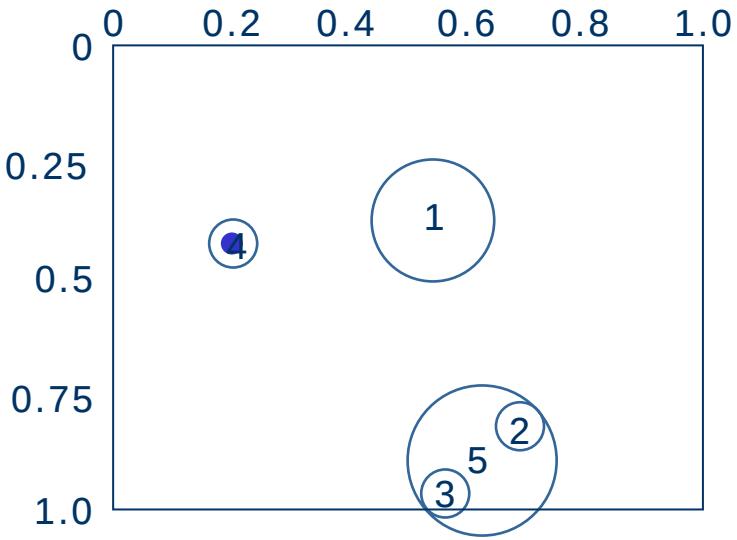
**Threshold:**



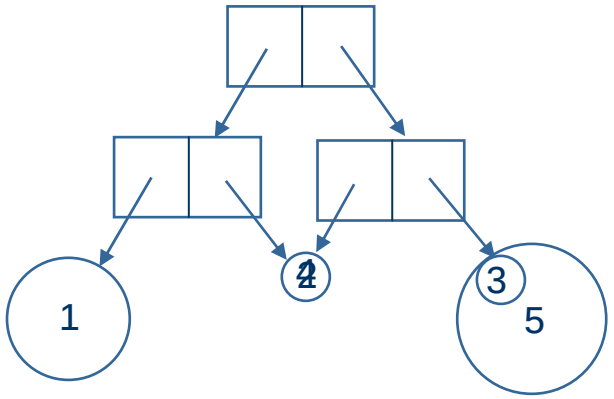
**Max Number of Clusters: 3**

**Branching factor: 2**

**Data Space**

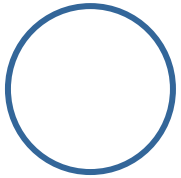



**CF Tree**



# ADWICE detection

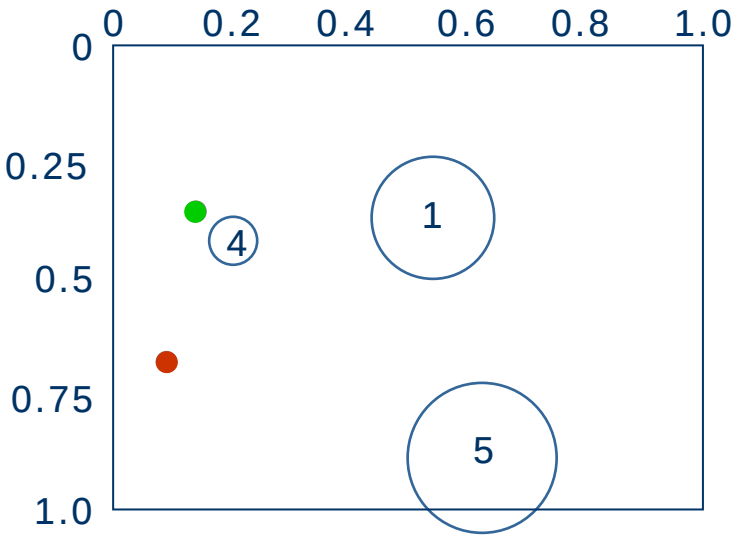
**Threshold:**



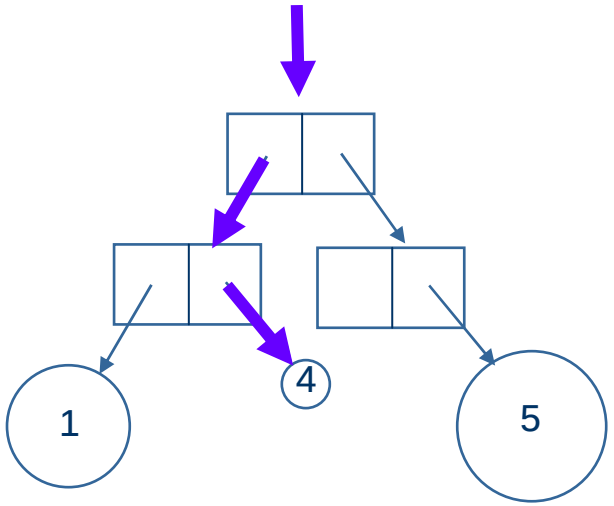
**Max Number of Clusters: 3**

**Branching factor: 2**

**Data Space**



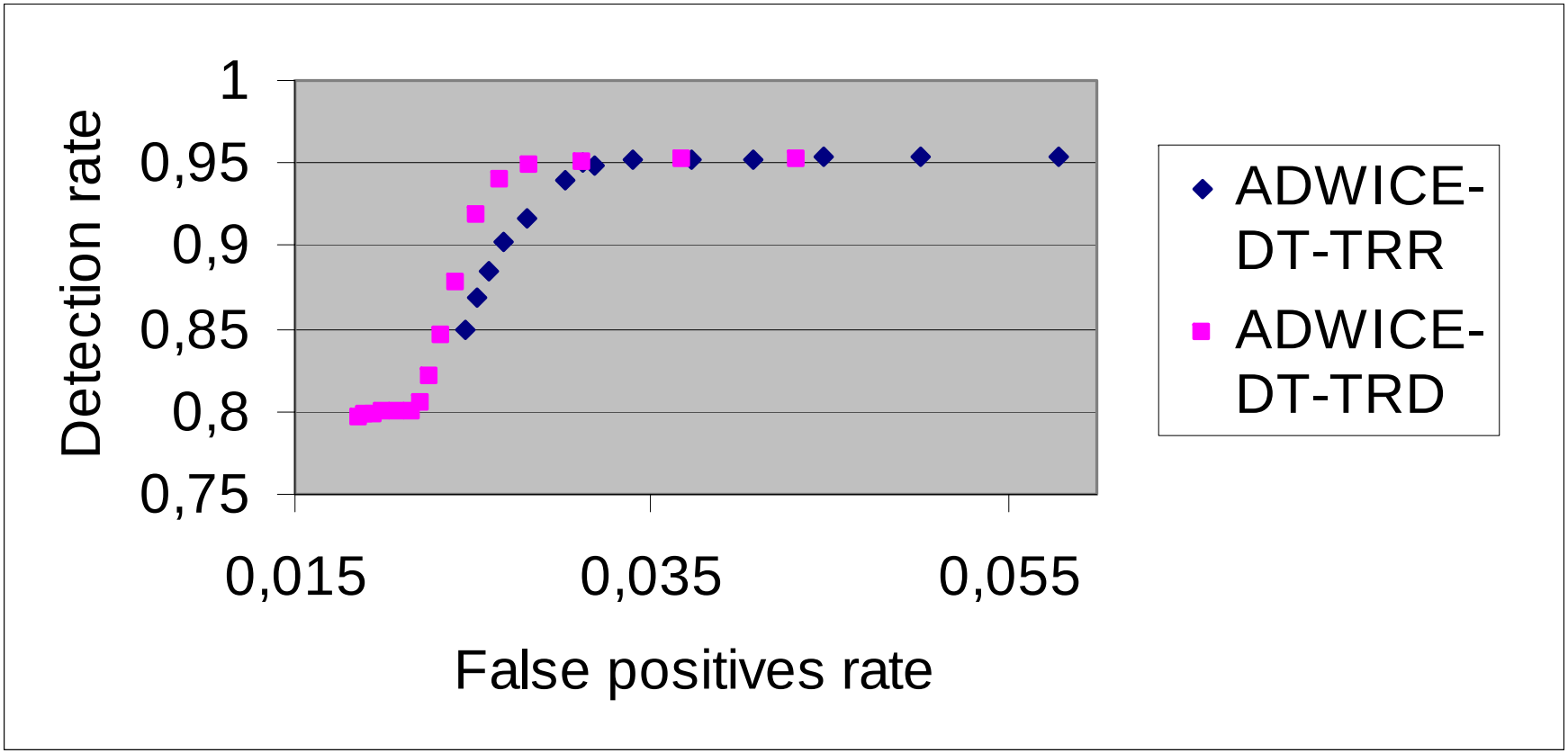

**CF Tree**



# Evaluation

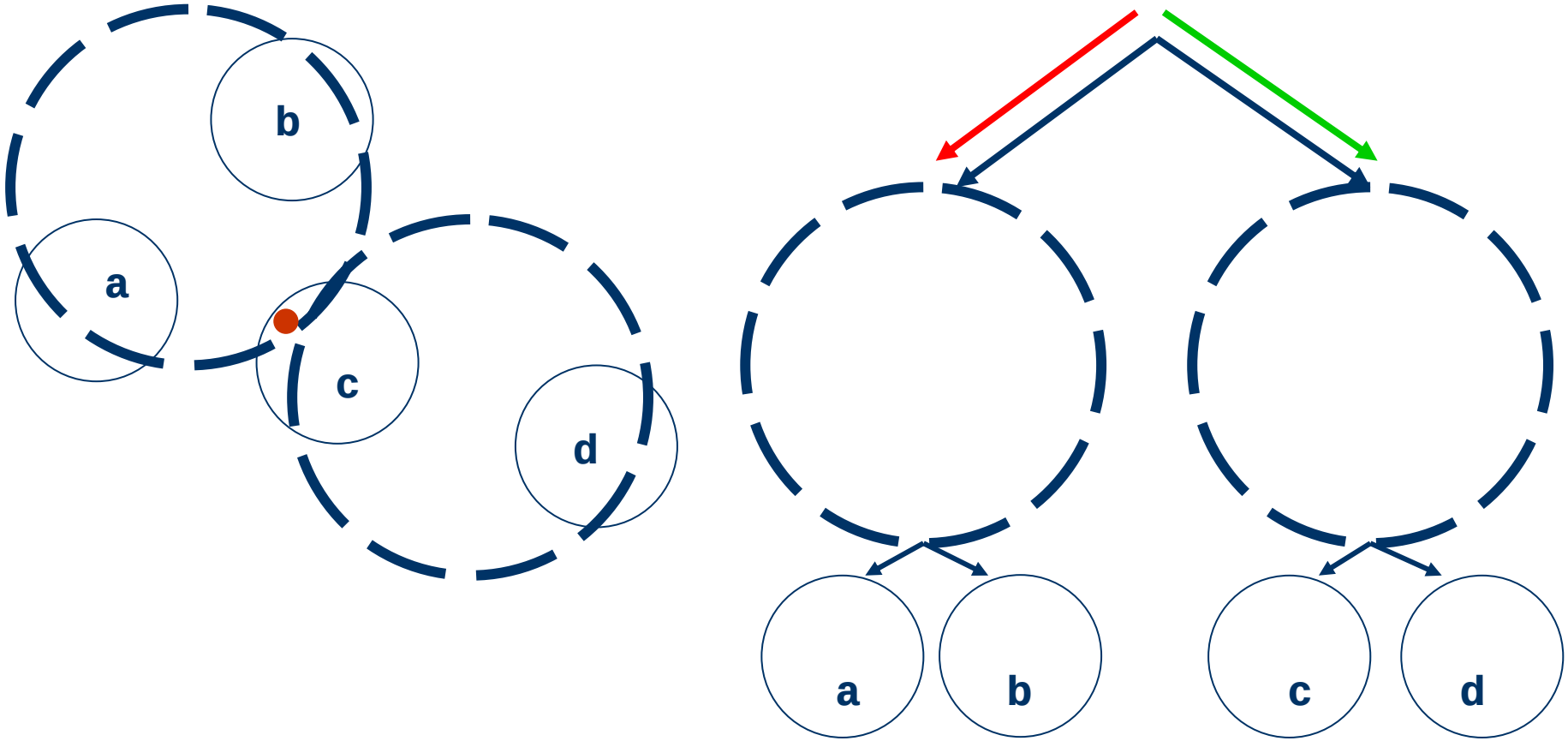
- KDD99 Data
- General properties
  - Session records (TCP/UDP summaries)
  - 41 features (flags, service, traffic stats ...)
- Training data
  - 4 898 431 session records
  - 972 781 normal, the rest (attacks) not used
- Testing data
  - 311029 session records
  - normal data and 37 different attack types

# Detection rate vs. false positives



# Index errors

- Some false positives are due to index errors

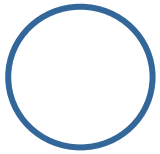


# ADWICE-Grid

- A new version of the algorithm: separates cluster formation and index updates
- How does ADWICE- Grid work?

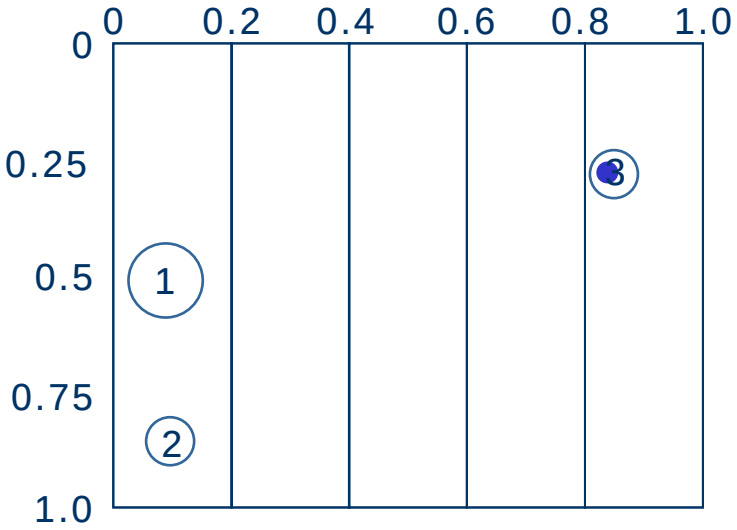
# ADWICE-Grid: Training

**Threshold:**

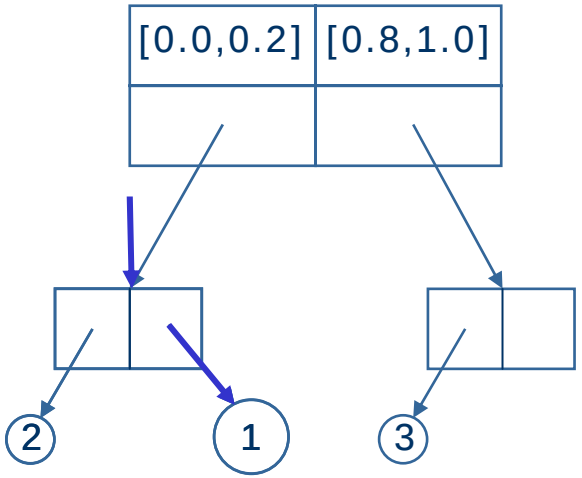


**Max clusters in Leaf: 2**

## Data Space



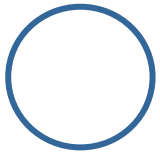

## CF Tree



# ADWICE-Grid: Training

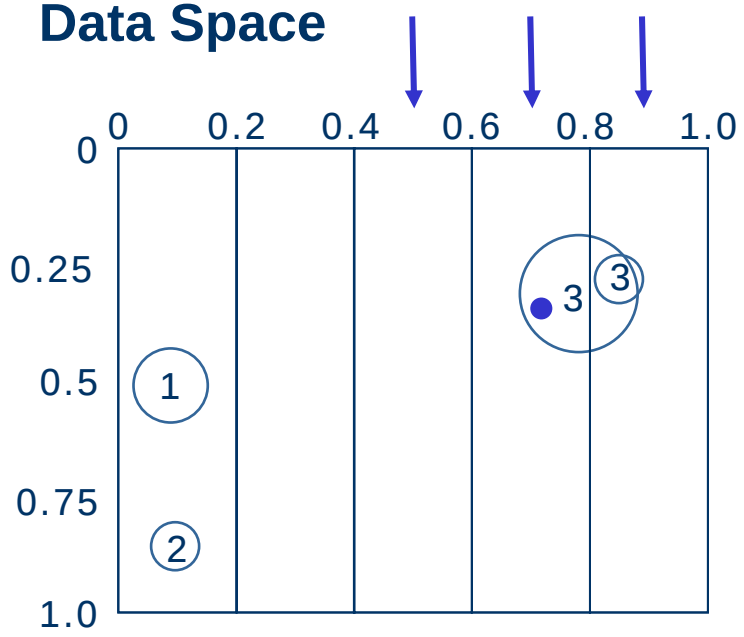
**Threshold:**

**(Search width)**

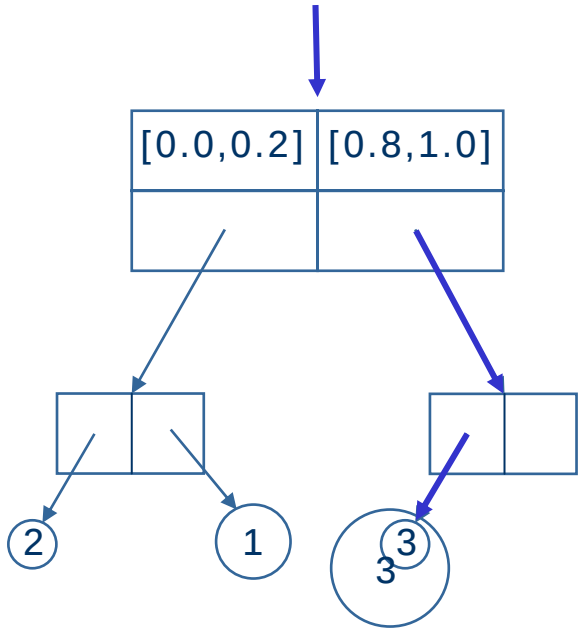


**Max clusters in Leaf: 2**

**Data Space**

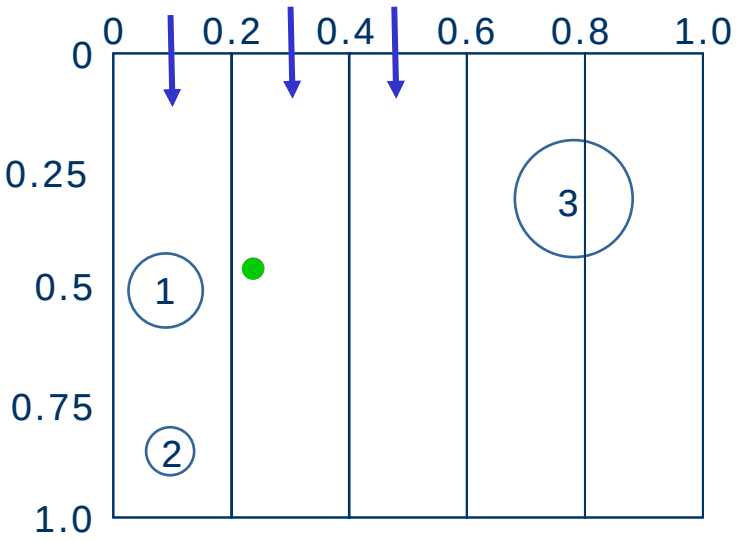



**CF Tree**

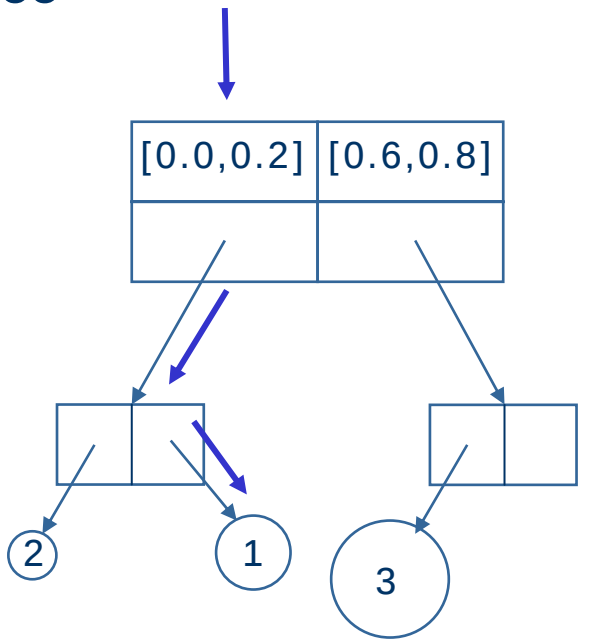


# ADWICE-Grid: Detection (1)

## Data Space

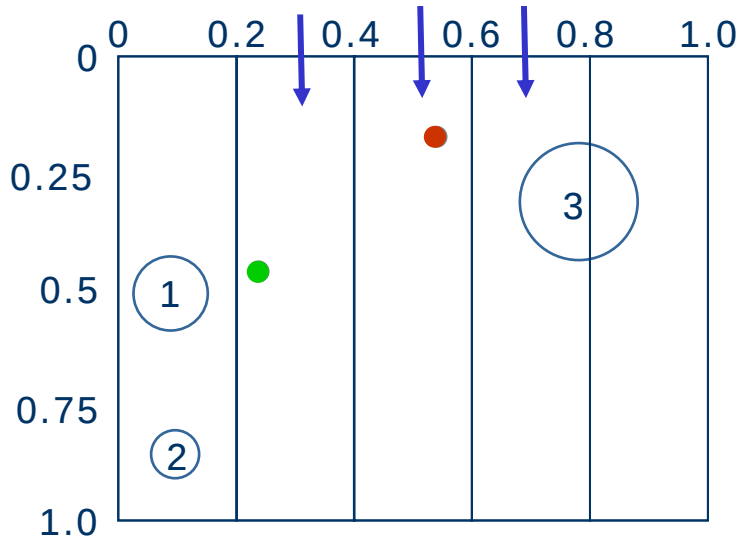



## CF Tree

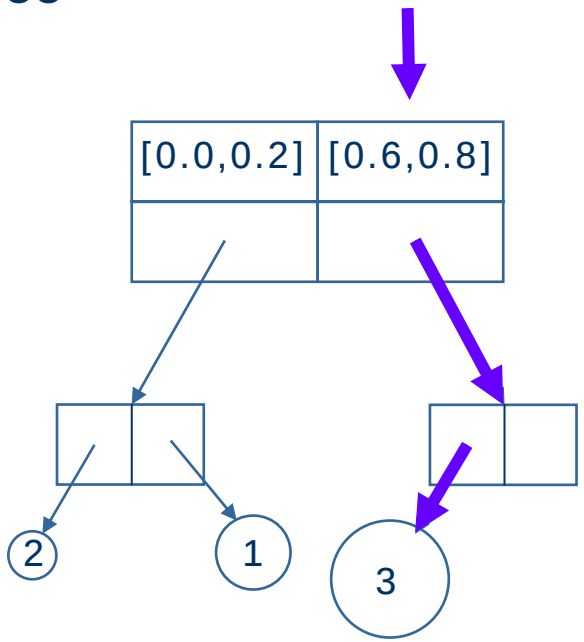


# ADWICE-Grid: Detection (2)

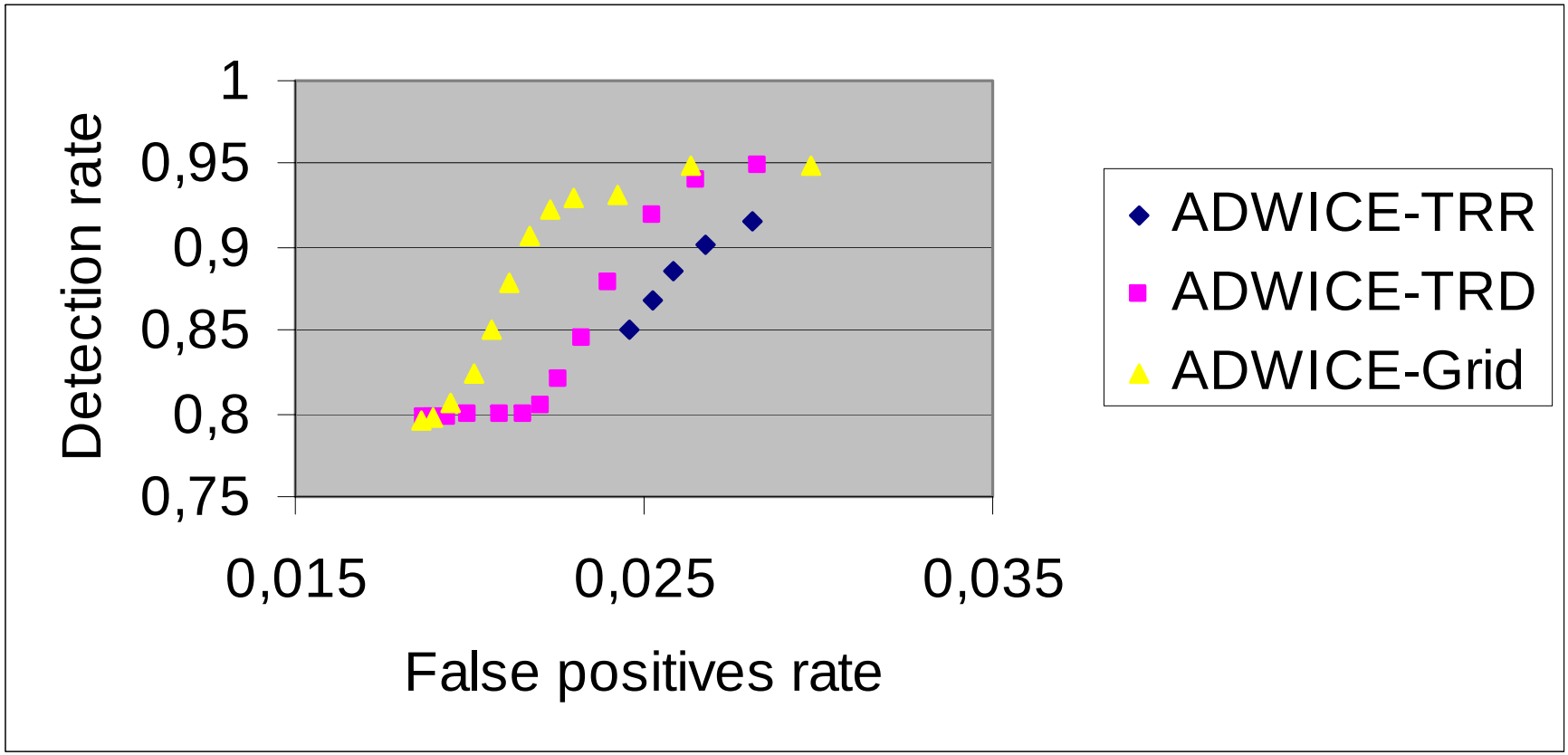
## Data Space




## CF Tree

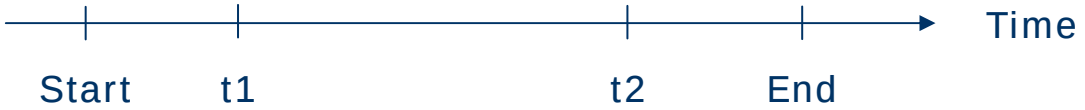


# Detection rate vs. false positives



# Alarm aggregation

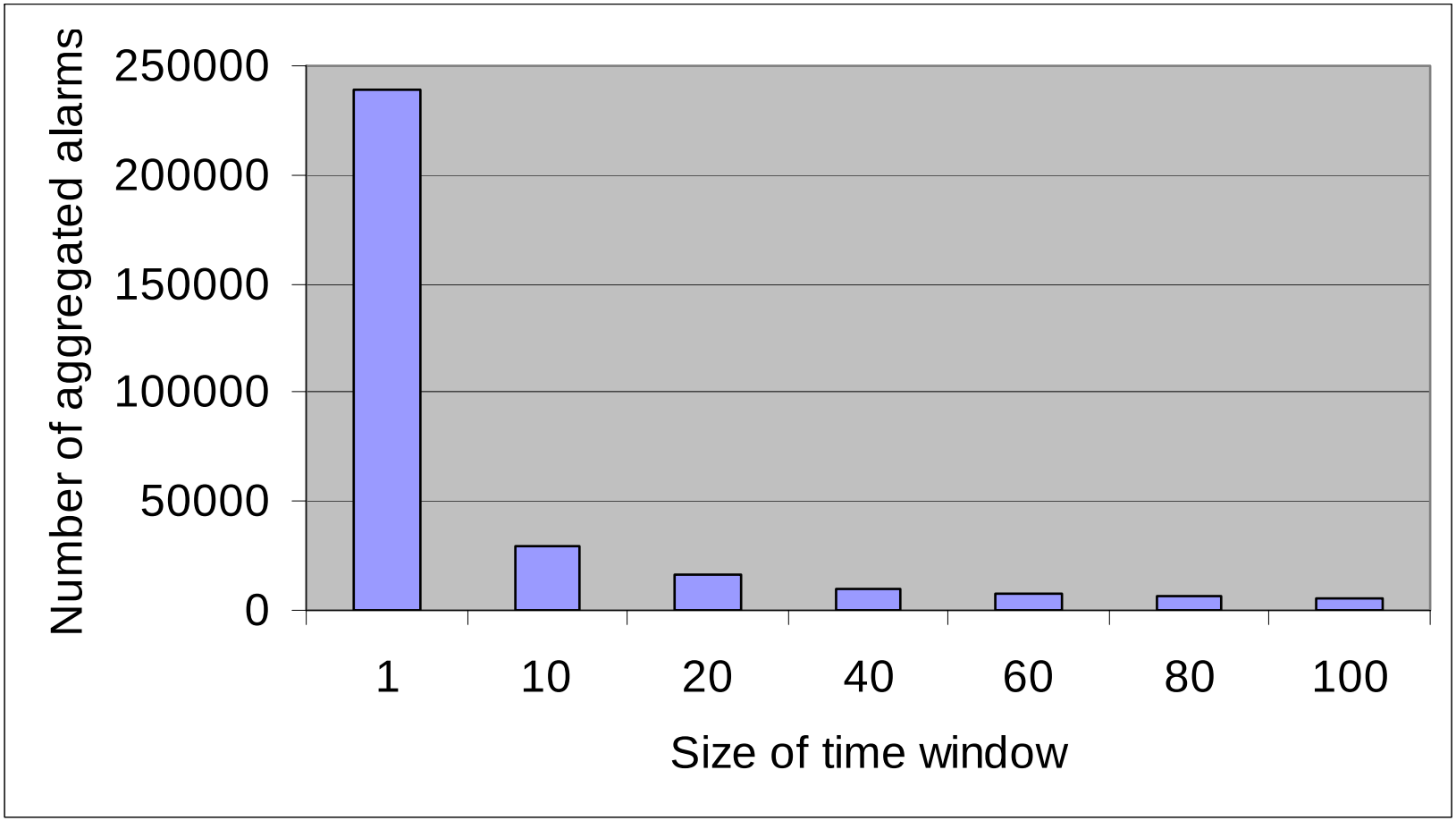
- Anomaly detection may produce many similar alarms (e.g. DoS, Probes, False positives)
- Similar alarms can be aggregated without losing accuracy



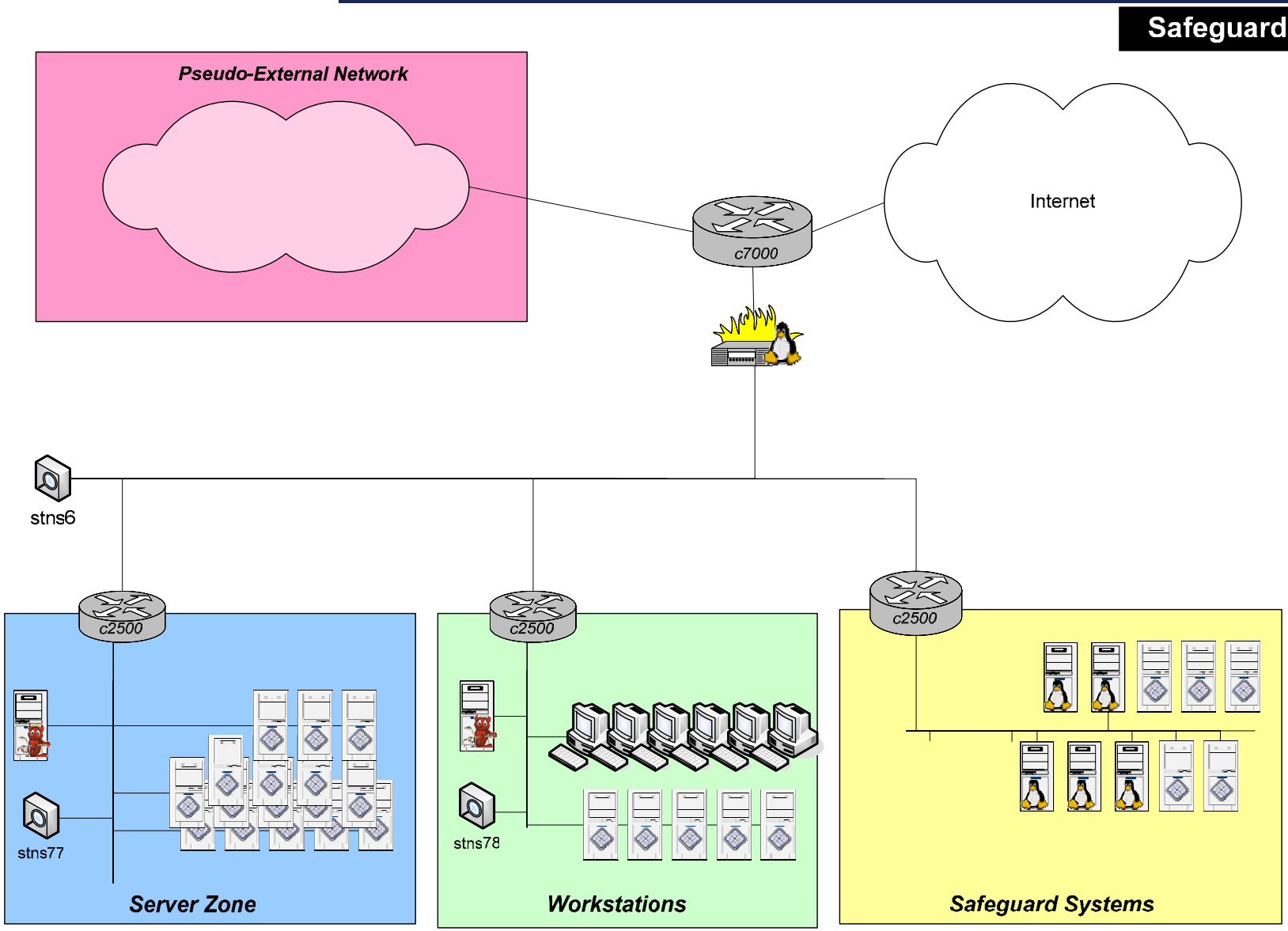

*Normal alarms:* <t1,HTTP, ...> <t2,HTTP, ...>

*Aggregated alarm:* <Start, End, Count = 2, HTTP, ...>

# Alarm aggregation results

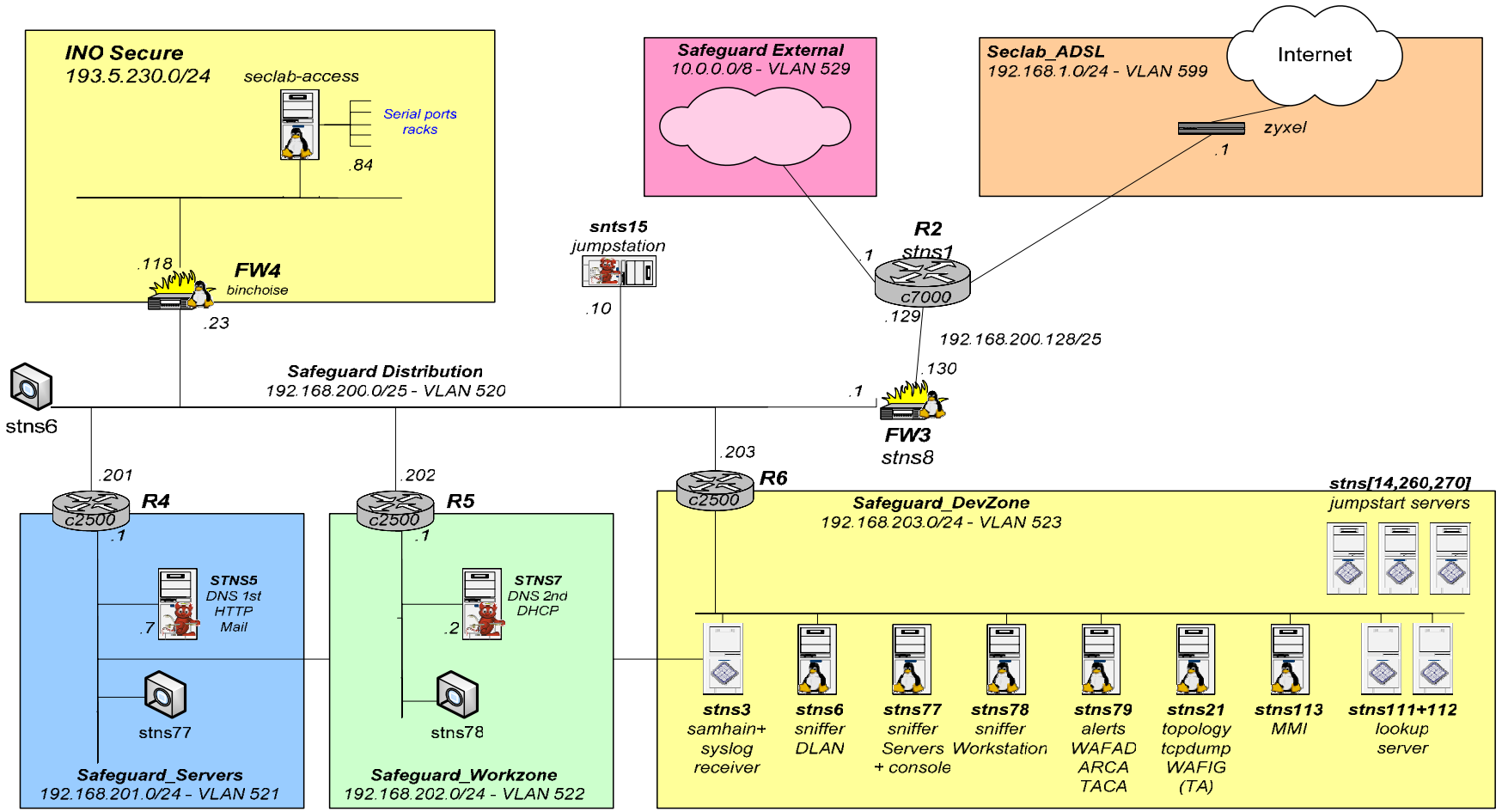


# Safeguard 100+ test network

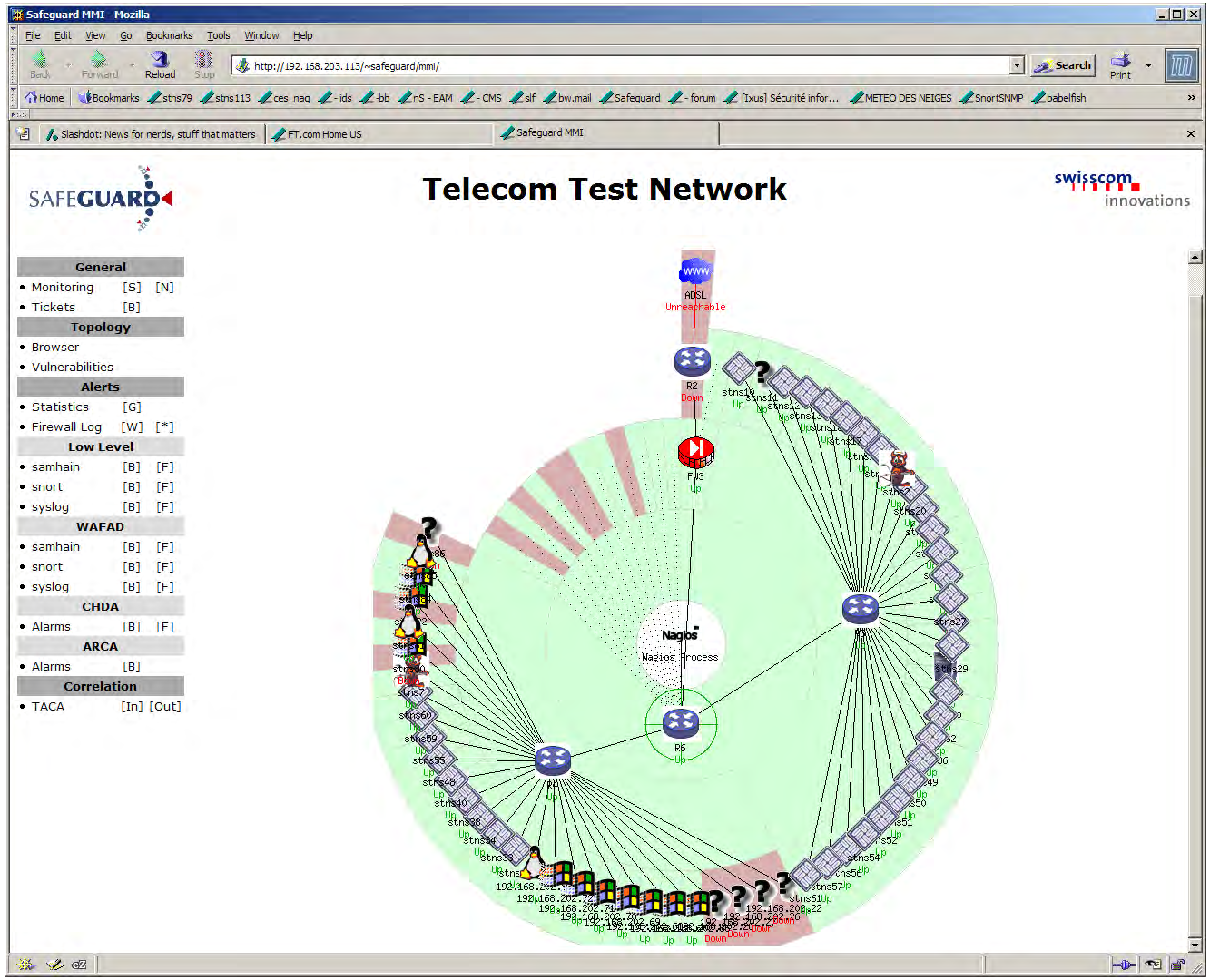


# Agents deployment

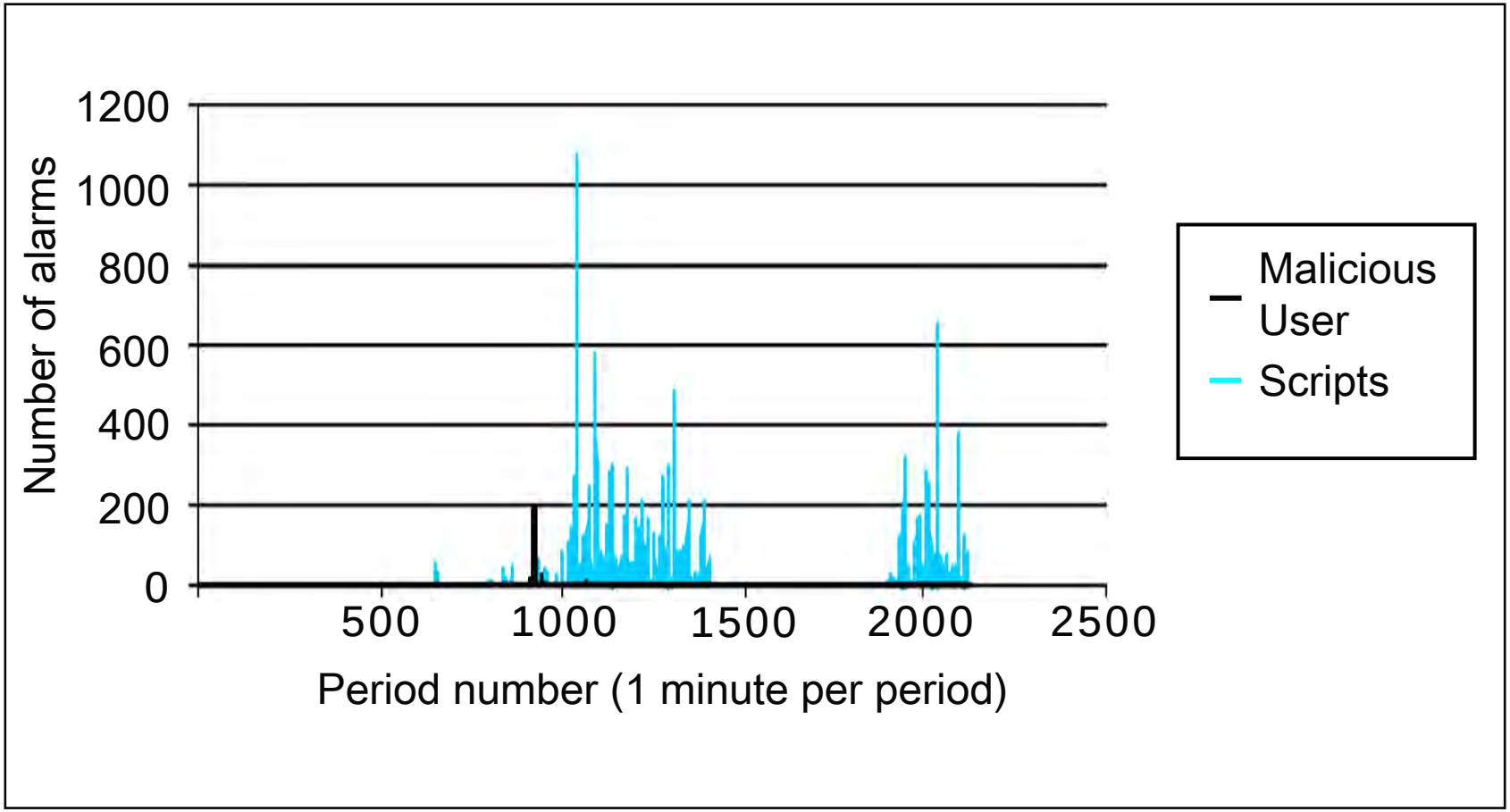
**Safeguard**



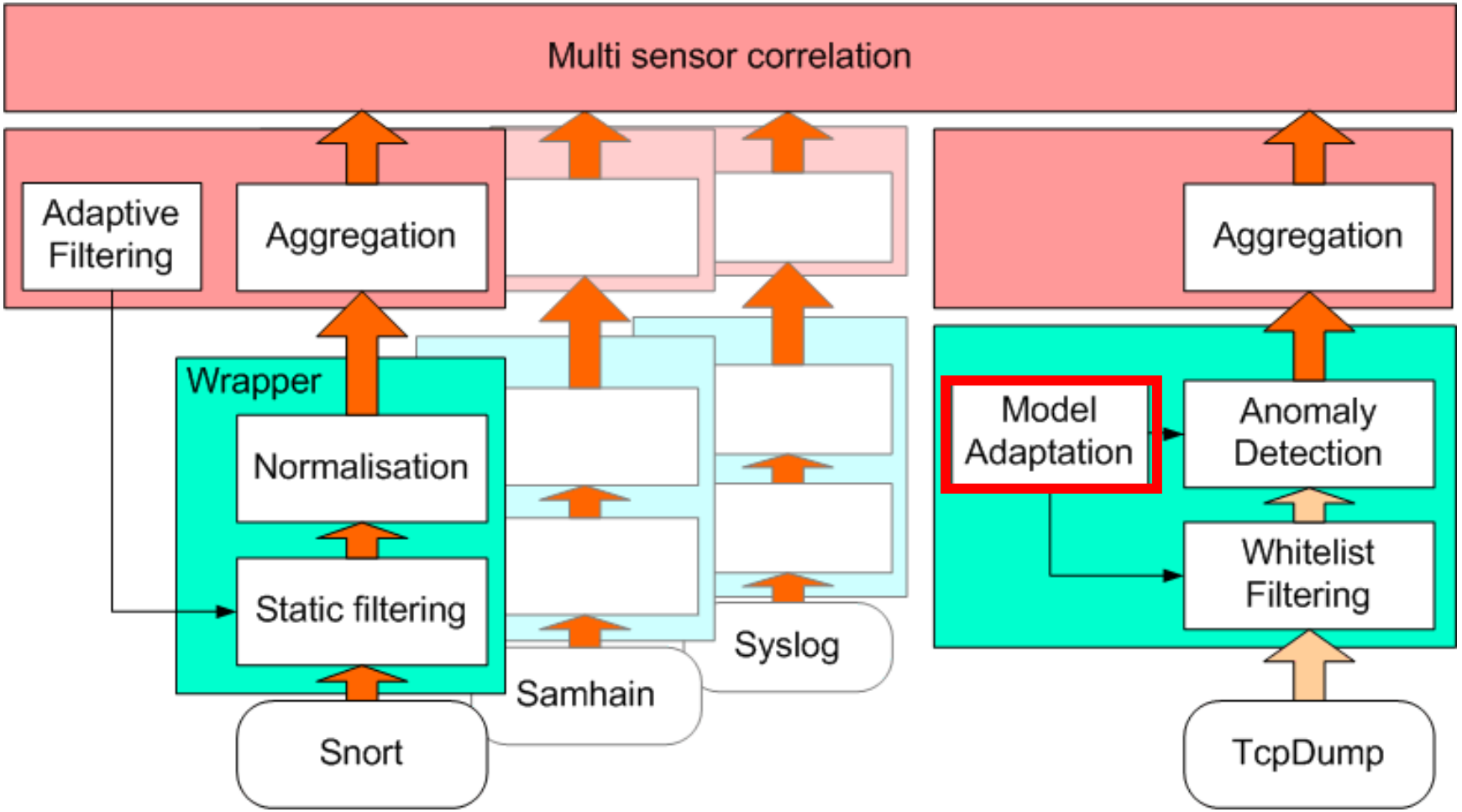
# One HMI agent interface



# A Safeguard scenario

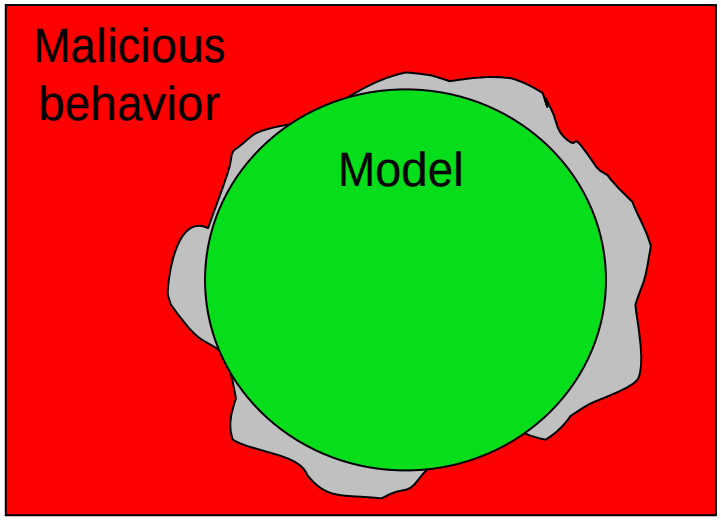


# Correlating alarms



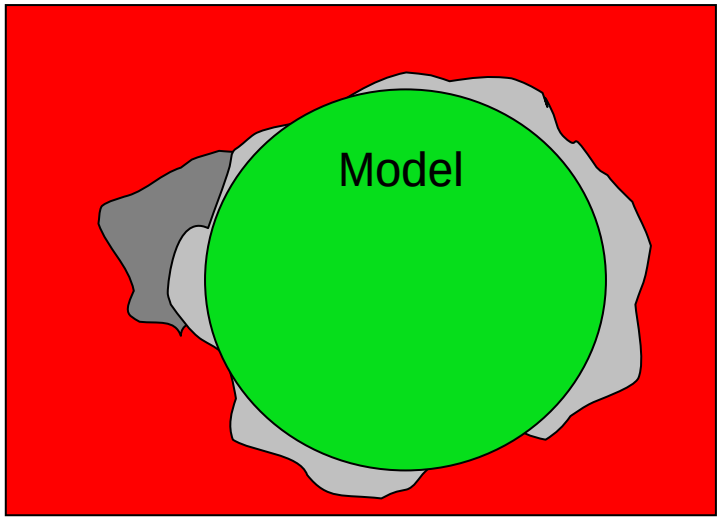
# Need for normality adaptation

- Normality is not static!



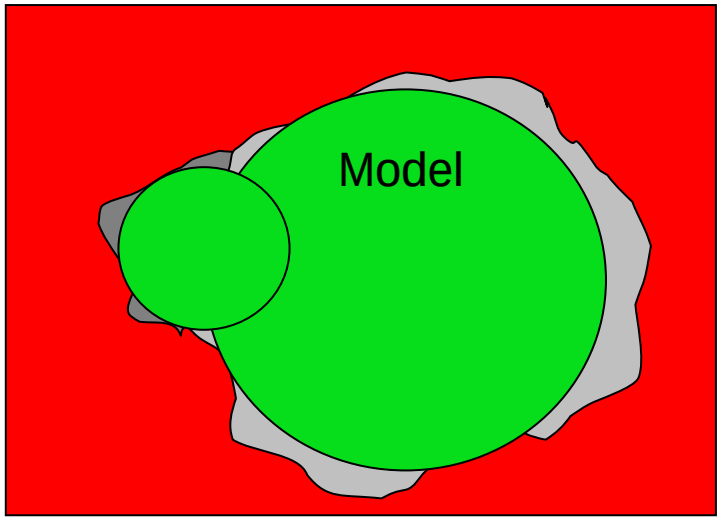
# New cases of normality

- Normality changes
  - New type of normal behaviour
- Old model incomplete
  - Evaluation using KDD data gives ~300 false positives for new normality

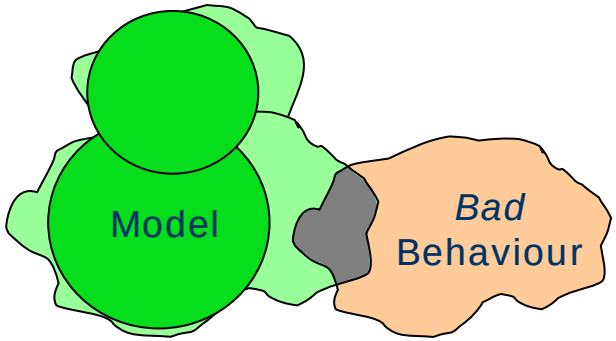


# Evaluation of normality adaptation

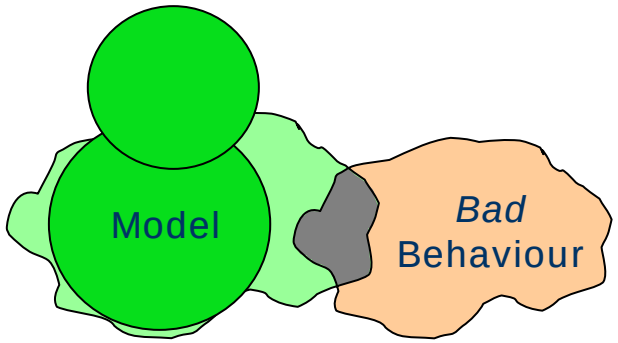
- Admin or system reacts
  - Recognize new false positives
  - Tells ADWICE to learn this behaviour
- Normality model adapted
  - From 300 to 3 false positives!



# Forgetting




- System keeps track of model usage
  - If time since last usage is very long for subset of clusters
  - Decrease size (influence) of those clusters and finally remove them if not used



# Lessons Learnt

Safeguarding critical infrastructures needs:

- Adaptive elements
- Incremental and scalable algorithms
- High performance for large volume of data

- Demonstration on realistic test beds
  - Research on open data sets :-)

- Understanding  and mitigating interdependencies

# Current track

- Application of ADWICE in anomaly detection for water management systems
  - Cooperation with Environment Protection Agency (EPA), USA
  - 50 scenarios: Time series data from simulated water system over an interval of one week
- Banking applications (Luxembourg ☺)