Joint Laboratory for Petascale Computation

A detailed analysis of fault prediction results and impact for HPC systems.

Ana Gainaru, Franck Cappello, Bill Kramer

Motivation

- Log files give useful information
  - Systems generate events about hardware, application, user actions
- Classic data mining workflow:
  1) Group events of same type in clusters
  2) Filter redundant events (in space and time)
  3) Correlation analysis (explore time or/and space dependencies)
  4) Event or failure prediction.
- Best result so far: Good precision (80%) and recall (70%)
  - From failure logs (not event logs) + Resource Usage log
  - Very long training phase (predicting 1 month from 9 months of training)
- Observation
  - Different error types present different distributions
  - Analyze behavior differences in all events

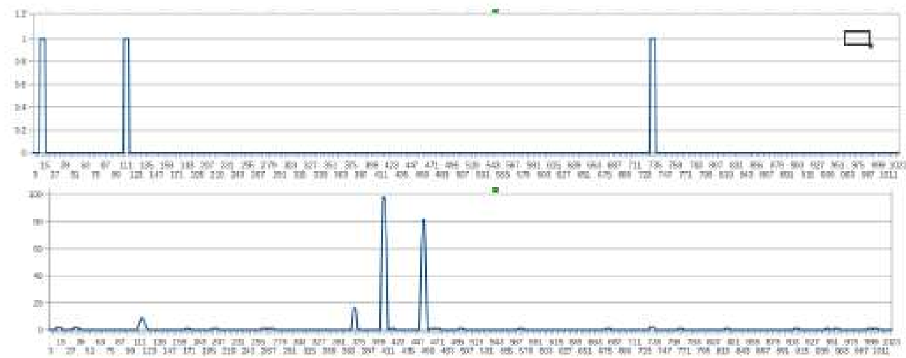
Hybrid method

- Signal analysis
  - Occurrences of each event types are considered as time series
    - Different event types become different signals
  - Variation in signal's normal behavior identifies suspicious events that could represent failures
  - Easy to shape and characterize different behaviors
- Data mining
  - Optimized on finding patterns
    - Correlation extraction
    - Fast online outlier detection

Joint Laboratory for Petascale Computation

Signal analysis

Silent signal
characteristic of error events. PBS errors

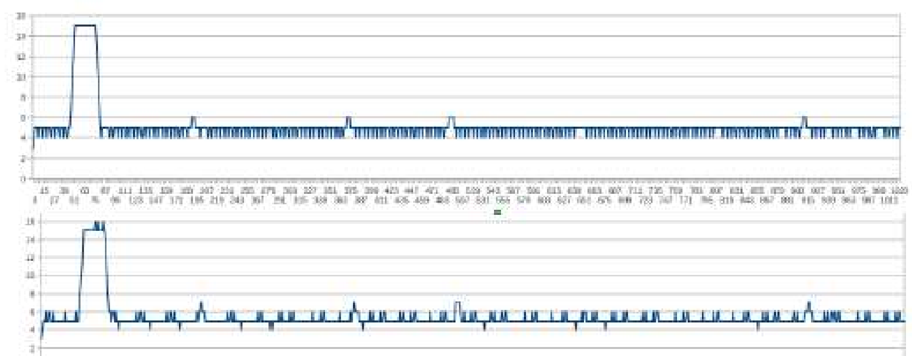


(a)

Noise signal
typically Warning messages: Memory errors corrected by ECC

(b)

Periodic signals
daemons, monitoring



(c)

Joint Laboratory for Petascale Computation

Table of contents

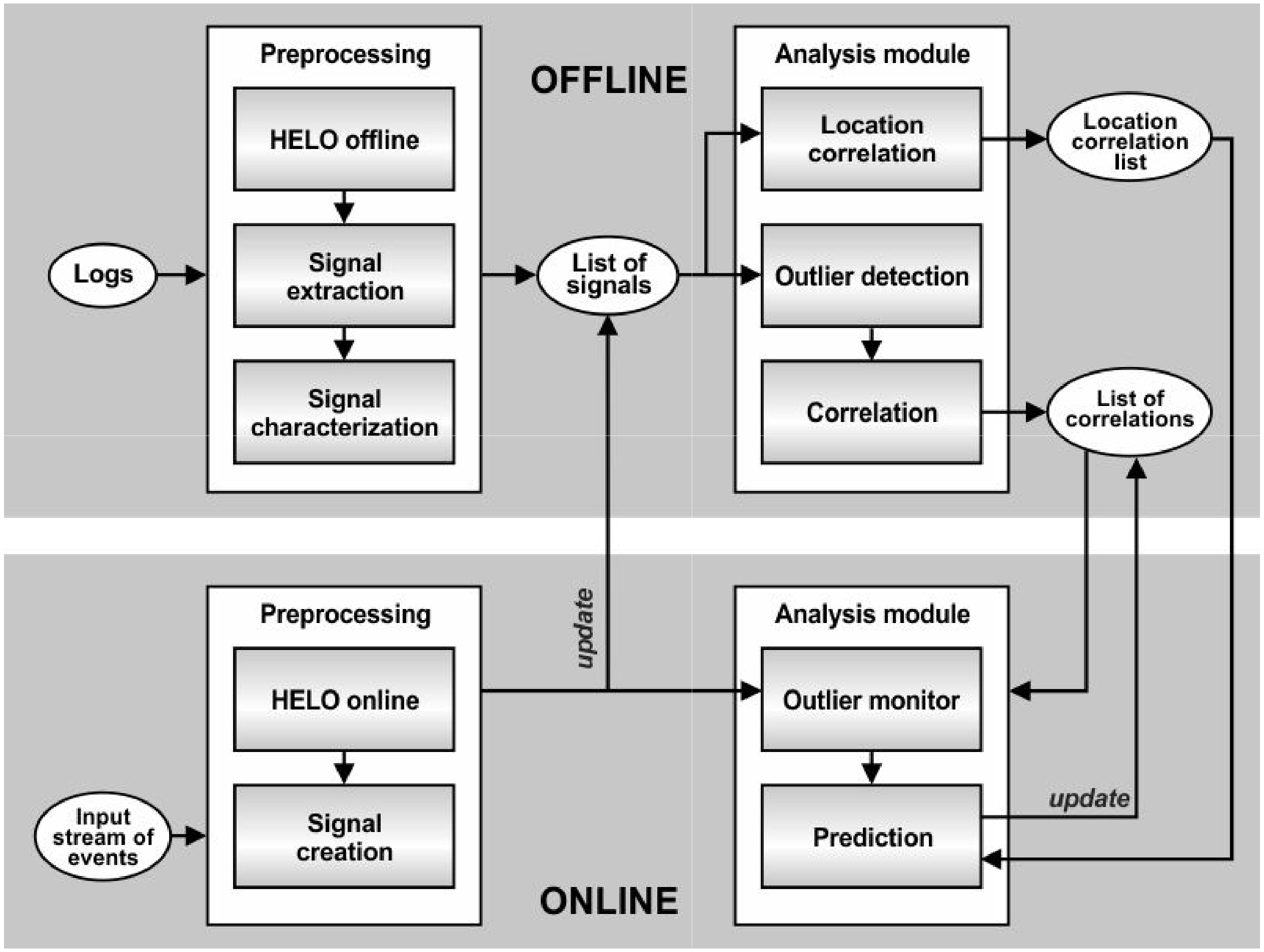
Pre-processing

- Looking for frequently occurring messages with similar syntactic patterns
  - HELO: Hierarchical Event Log Organizer
- Signal extraction
  - Use a sampling rate (different depending on the signal)
  - Map number of events for each sample

Template	**Event type**
failed to configure resourcemgmt subsystem err = 10	Processor cache error
psu failure	PSU failure
component state change: component * is in the * state *	State change in a component

Table II
EXAMPLES OF TEMPLATES AND THEIR EVENT TYPES

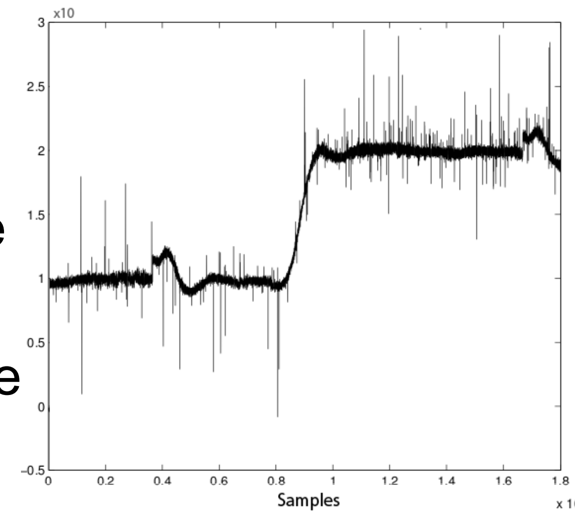
Methodology

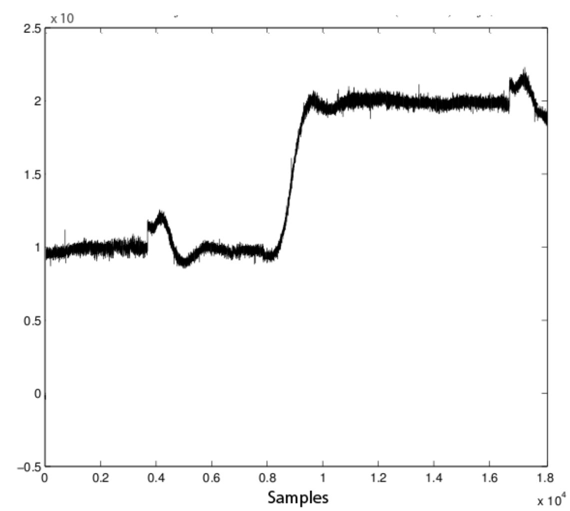


Analysis modules

1) Outlier detection

- Causal moving data window
  - Each observed data point is compared to the median
  - Based on the distance between the points we detect outliers
- Threasholds
  - 2 months time window
  - Different distance values automatically selected
- Advantages
  - Decrease the influence of severe outliers on signals

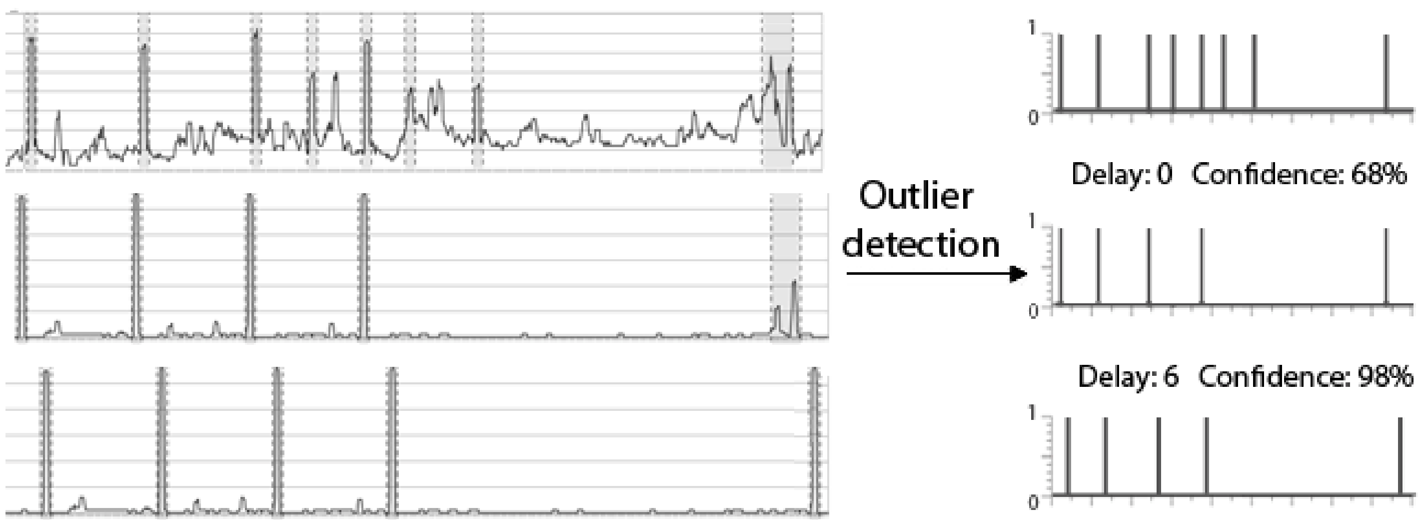




Analysis modules

2) Signal correlation

- Data mining algorithm
  - Filter out the normal behavior
  - Apply a algorithm based on the GRITE data mining algorithm
  - Tree-based exploration – multi-set correlations



3) Location correlation

- Set of locations that events propagate on

Results

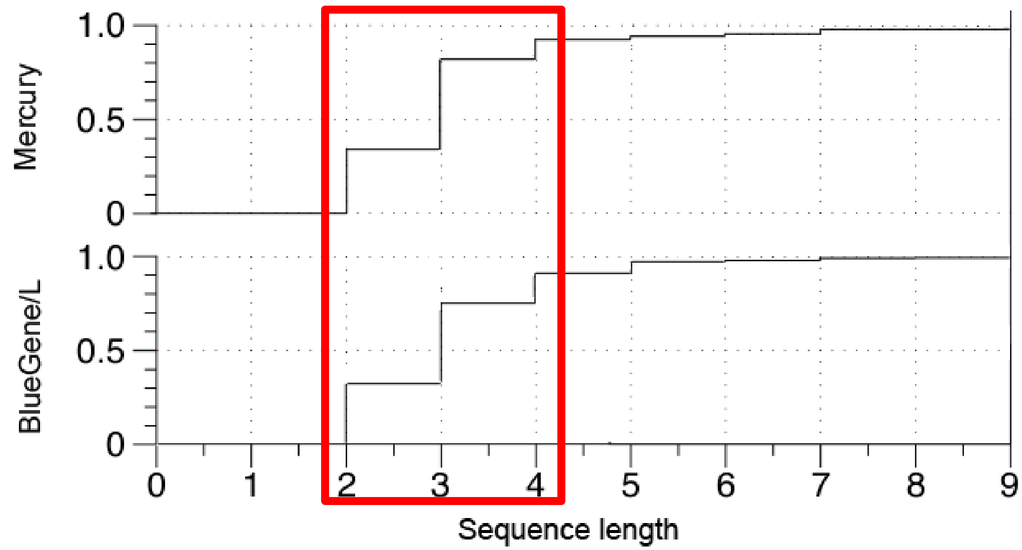
- Experiments on BlueGene/L
  - Offers information about event severity
  - Analyze location prediction
  - Additional experiments on Mercury
- Correlations
  - Patterns, breakdown on different components
- Prediction
  - Precision, recall, time between prediction and occurrence

Signal Correlations

- Examples of correlations
  - Memory errors
    - Starting: *correctable error detected in directory* *
    - Ending: *parity error in read queue* *
    - Time delay: around one minute
  - Node card errors
  - Multi-line messages
  - Component restart sequences
- 23% cannot be used for prediction
  - Refer only to informational messages
  - Eliminate all events with INFO severity

Signal Correlations

- Dissection
  - Distribution of the events that compose a sequence



  - Time delay between correlations

Pairs of correlations

33.6% have at least 10 seconds

7.8% have at least 1 minute and

2.1% over 10 minutes

Complete sequences

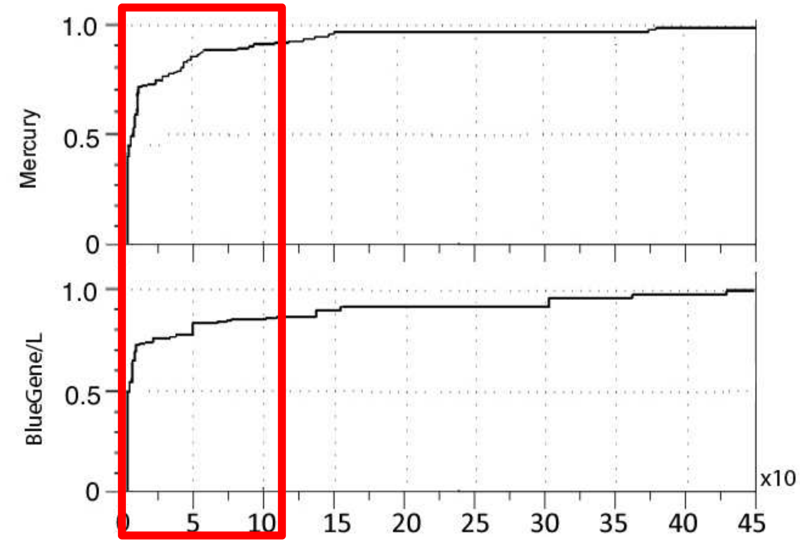
54.1% have at least 10 seconds

19.4% have at least 1 minute and

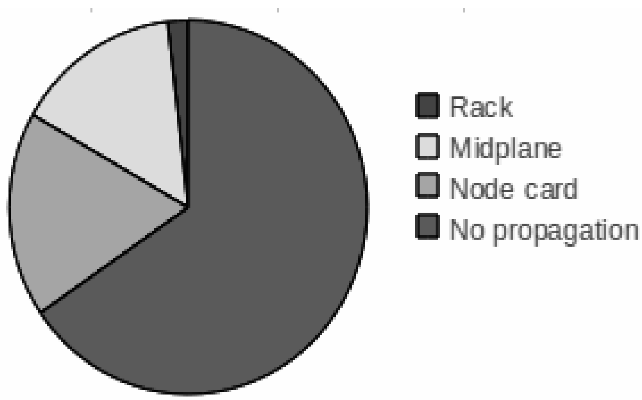
5.7% over 10 minutes

Location Correlations

- Propagation behavior
  - Around 20-25% events propagate
  - Cumulative distribution of the number of different locations per chain



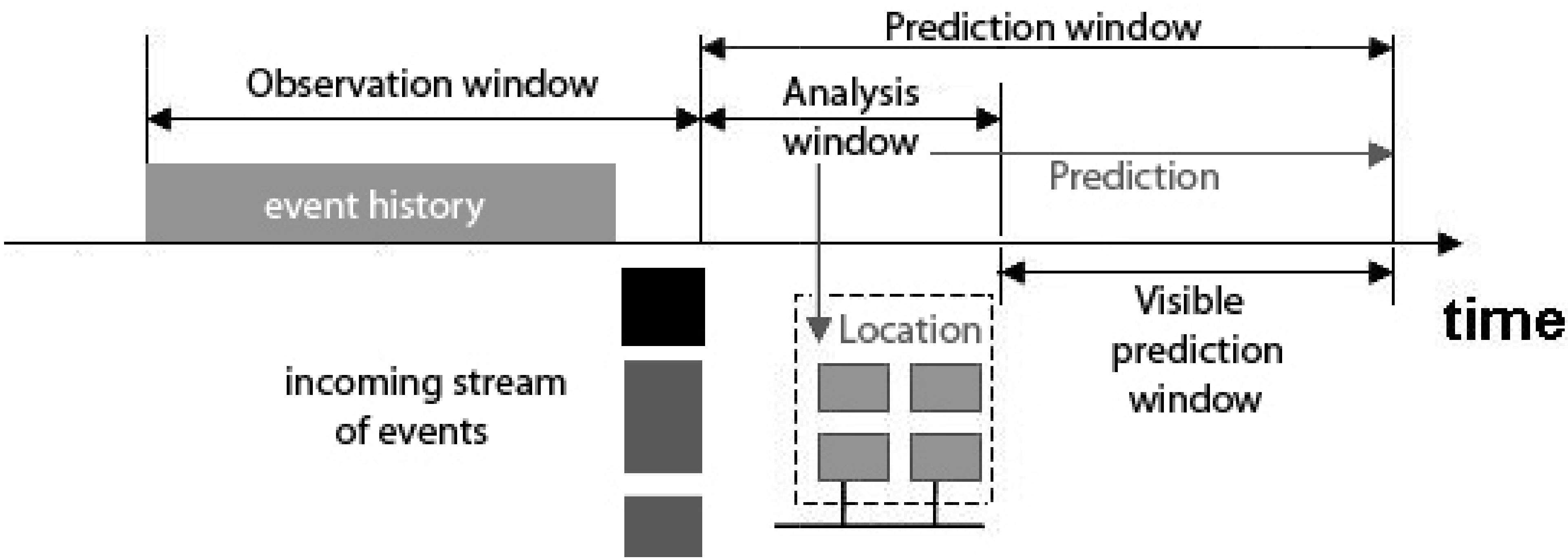
Example: NFS (network file system) on Mercury



- Propagation break down
  - Initial pair of correlated events
  - 76,92% show no propagation
  - 2.16% expend outside the midplane

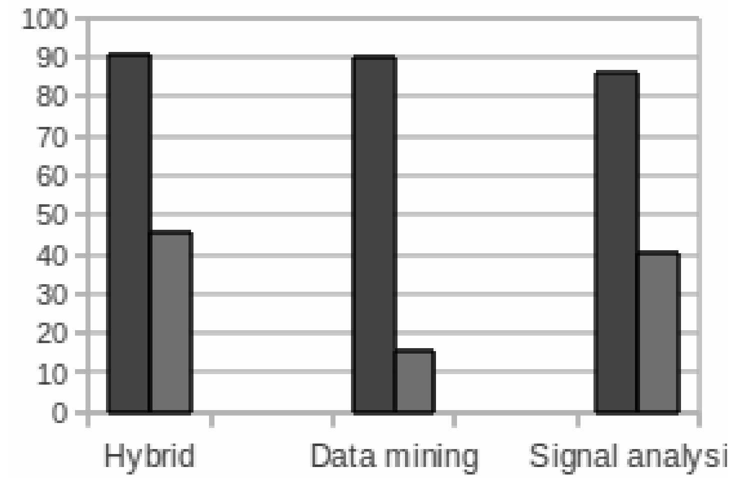
Prediction

- Prediction process overview
  - Visible prediction window



Precision and recall

- ## Prediction results
  - Analysis window: avg 2 seconds, worst case 8.43
  - Signal analysis - many sequences, small length
    - Higher analysis window
  - Data mining approach
    - Looses correlations between signals of different types
  - Location prediction results
    - 93% to 86% precision
    - 43% to 40% recall
  - Force best precision

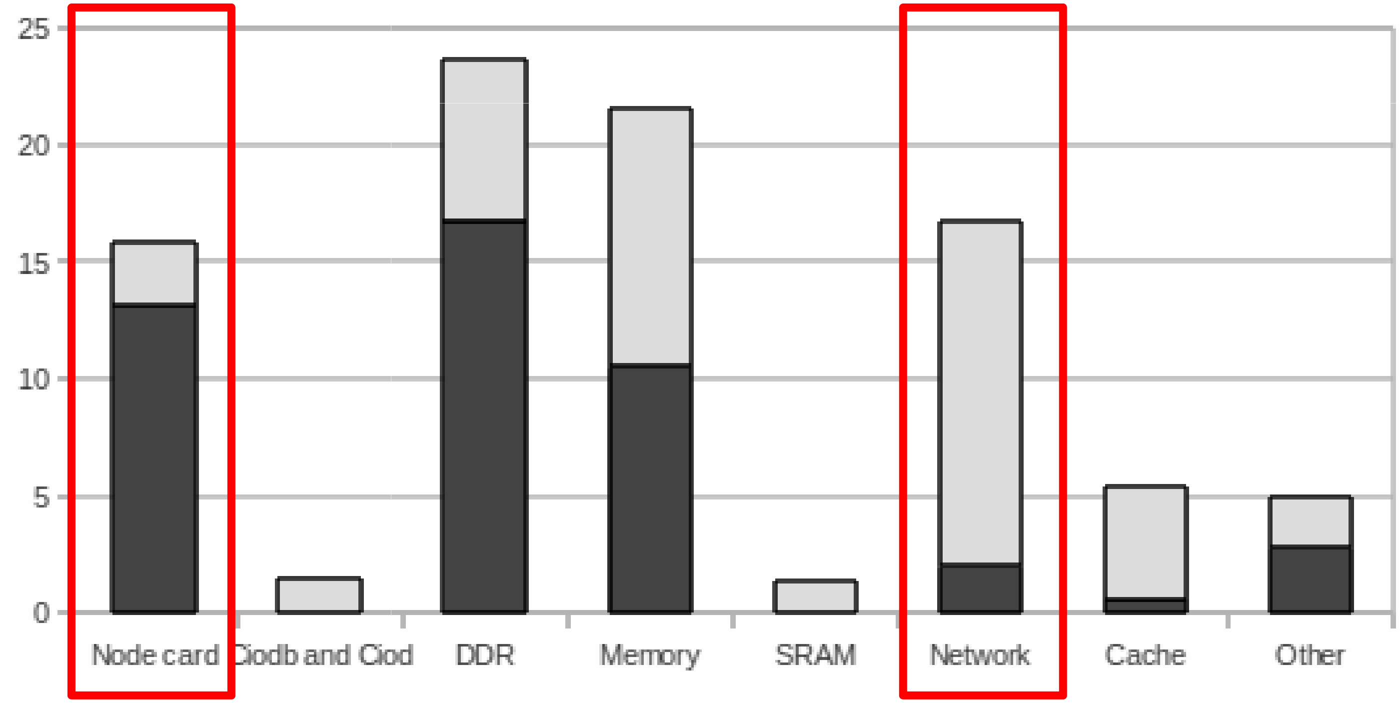


Prediction breakdown

- Appearances of different error types
  - reported to all errors in the system
  - dark: correctly predicted cases out of total occurences

Best case: nodecard
- Over 80% predicted

Worst case:
- Around 10%



Other observations

- Sequence use for prediction
  - 23.5% of sequences are used in over 90% of the cases
  - 2.5% of sequences are never used for prediction

- Visible prediction window
  - 85% of the prediction offer more than 10 seconds
  - 36.6% of the total failures on BlueGene/L are seen with more than 10 seconds in advance

Impact on checkpointing

- Analytical model
  - Start with the formula from describing the waste for a checkpointing strategy from [1]
    - Accounts for checkpointing time, recovery time and the lost due to faults
  - Include a prediction with a precision and recall
    - Changes the mttf, adds the waste of taking checkpoints when predicting an error, adds the waste when the prediction is wrong
- For C = R = 5 , D = 1 minutes

Mttf	Precision	Recall	Waste
1 day	92	36	10.4%
5 h	90	50	22%

[1] F. Cappello, H. Casanova, and Y. Robert: Checkpointing vs. migration for post-petascale supercomputers. International Conference on Parallel Processing, 2010

Conclusions

- Signal analysis
  - Different event types may have different normal behaviors
  - Faults affect event types in a different way
- Data mining
  - Correlations
  - Location prediction
- Apply the model for fault prediction
  - Precision of 90% and recall of 40%
  - Prediction over 10 seconds before event

Future work

- Noise in each analysis step
  - Optimize the steps that influence the results
- Breakdown on components
  - Shows uneven distribution on precision
  - Better understanding for certain error types
- Fault distribution after prediction
  - Better analytical model
- Combine the prediction module with a checkpointing strategy

Thank you

?

Ana Gainaru (againaru@illinois.edu)

A detailed analysis of fault prediction results
and impact for HPC systems.