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Infrastructure for In Situ System Monitoring and Application Data Analysis

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U.S. DEPARTMENT OF ENERGY

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Motivation

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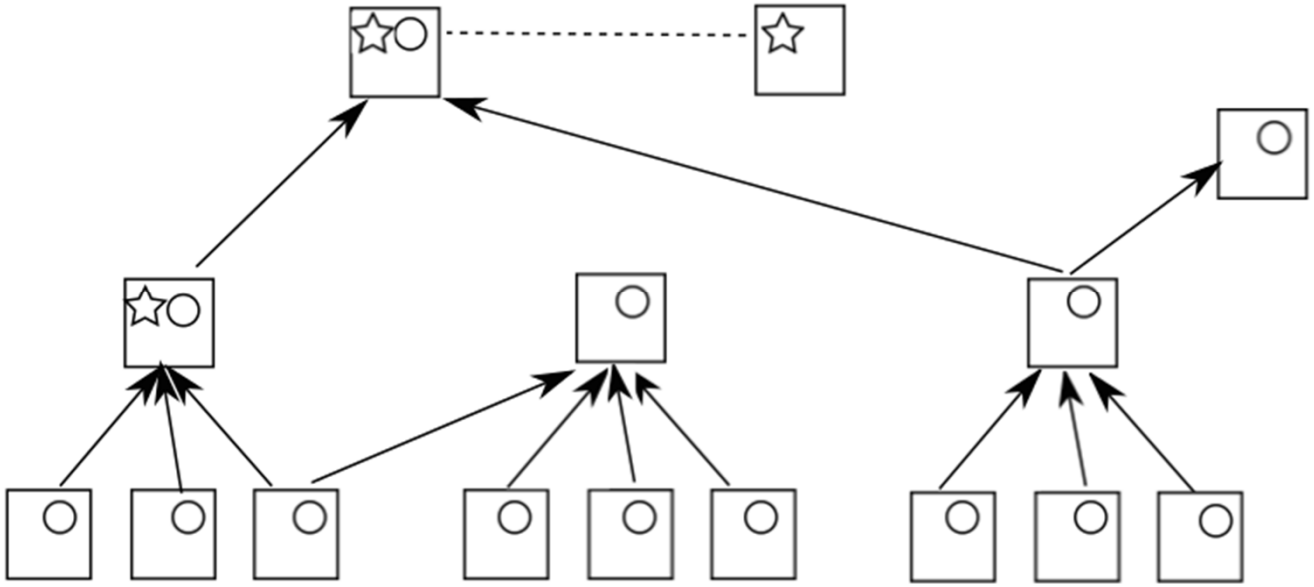
- HPC system monitoring and application execution typically separate
  - Applications have no insight into resource, particularly global, state
  - Monitoring systems send to centralized server, low collection frequency
- Expose system state data for run-time analysis within the monitoring system and to the running application:
  - Application gains exposure to privileged monitoring data
  - Lightweight monitoring system provides high frequency data
  - Integration provides low latency
- Use cases:
  - Power, CPU utilization etc.
  - Response to discovered contention for shared resources and dynamic events
- Goal: Provide a system service for applications and system software to improve execution and system performance

Architecture Overview



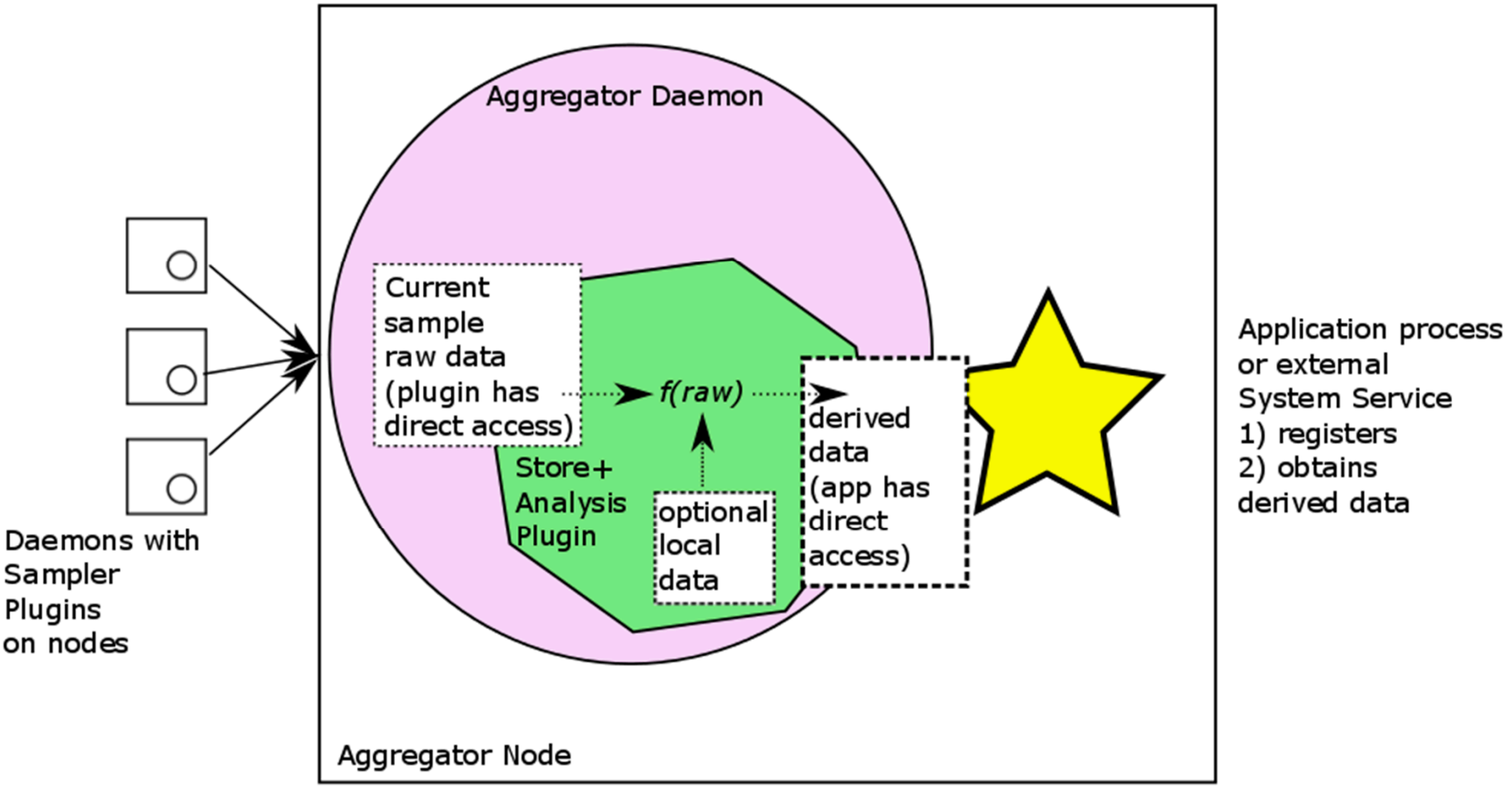
Star = application. No global data access

LDMS – lightweight monitoring with arbitrary aggregation topologies

- Circle = monitoring daemons
- *Continuous, full-resolution in situ data analysis via plugins as the data is resident in the aggregators*
  - Supports parallel analysis, use of run-time and historical data
  - Low-latency on-node access to results

Monitoring Analysis Interface

- Data consumer registers the intent to gather a defined set of data from the analysis plugin. Continuous analysis reduces latency.
- Memory mapped region can reduce latency
- Co-location of resource data, analysis, and application response



Dynamic Analysis and Response

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- Data Requirements:
  - Relevant but not jittery data
  - Reasonable expectation of future performance based on recent past
  - Fast in-situ analysis: redistribution vs analysis cost

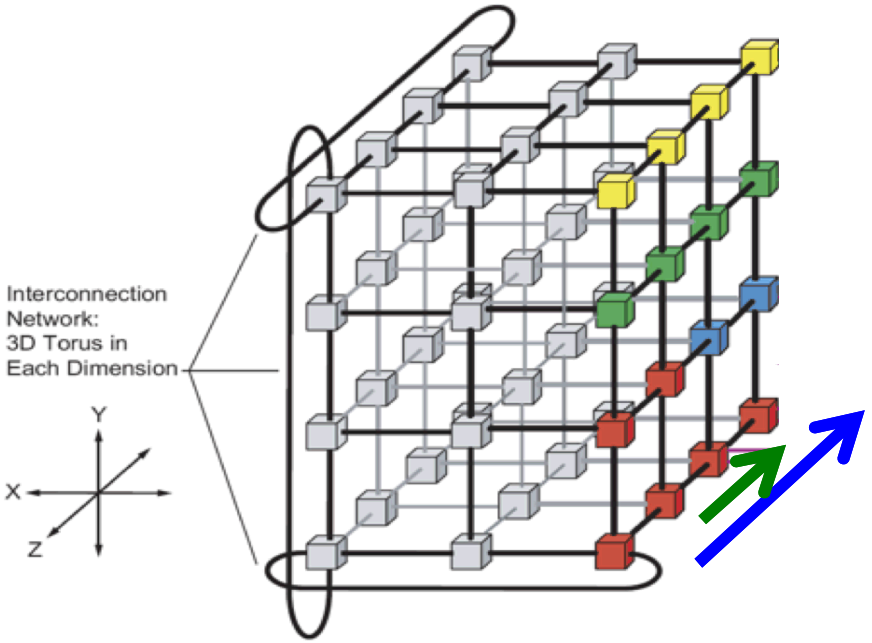
Use case: Analysis of network congestion and placement of MPI tasks on core to avoid detected congestion.

- Prior work: Can recover up to 49% of the execution time lost to congestion
- Goal: increase scale, decrease analysis time, reduce latency.
- New: Continuous analysis can proactively discover contention and trigger dynamic response

Network Congestion Analysis and Response

- Gemini network: 3D torus
- Traffic between source and dest is sent via a deterministic multihop route (X/Y/Z) (+/-)
- Congestion on intermediate and shared hops can affect performance. Info on those would not be accessible to an application.
- Congestion Measures:
  - Max % BW used
  - Max % time spend in stalls

  along the route



Analysis for Large Scale Systems

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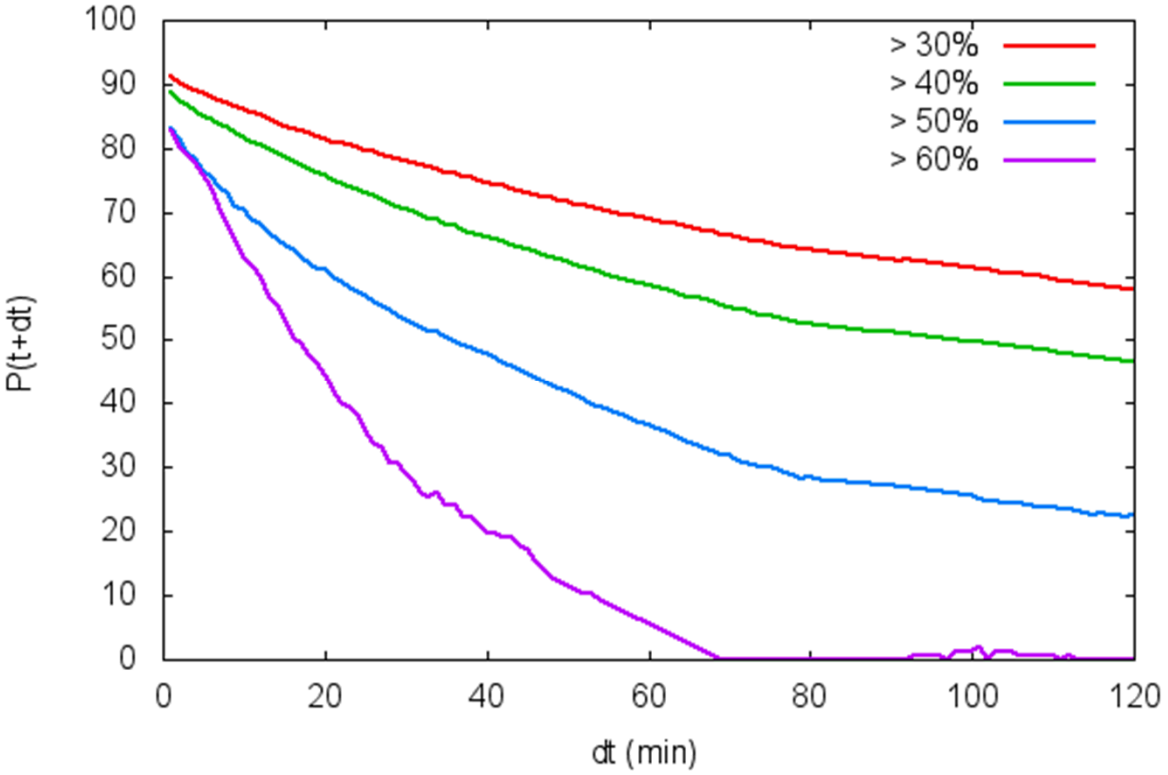
- Analyze data at run-time as it streams thru the aggregator
- Calculation reduction:
  - Brute force: 27648*27648 routes for NCSA Blue Waters
  - Register only for the routes of interest
  - Perform all routes' calculation in parallel
  - Calculation of max along a route can be done across multiple aggregators, each with a subset of the data, and then combined
  - Include only the most important components:
    - Significantly less congestion in Z+/-
- Privileged data -- More relevant interpretation:
  - Network quiesce events cause the values to drop although congestion is still high
  - Rerouting
  - Stale counter values

Change Detection and Response Triggering

- Probability of congestion duration on a given link
- Congestion infrequent (val >= 30% only ~0.6% of the entire day)
- Congestion endures (val >=50% has over 60% probability of being so 20 min later)



Discover congestion to advise other jobs to redistribute data

Characterizations can guide data collection/recomputation frequency

- X+ congestion (Max % time spend in credit stalls) duration from 1 day
- Data collected at 1 min intervals

Network Congestion Responses

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- Goal: Minimize cost of communications and/or data movement.
- Tools: Map geometric or graph-based representations onto each other to improve associations (e.g., reduce costs, minimize edge cuts)
- Congestion-aware Task Placement: Map tasks to nodes. Inputs:
  - Task graph (derived from the application) - Vertices represent MPI tasks. Weighted edges represent # bytes communicated between tasks.
  - Architecture graph (uses system information) - Vertices represent allocated nodes. Weighted edges represent cost of communication between nodes. More heavily congested paths between processors have higher weights.
- Congestion-aware Data Partitioning: Balance workloads and maintain locality. Inputs:
  - Application data graph (derived from the application) - Weighted vertices represent data and computational cost. Weighted edges represent strength of dependence.
  - Network graph (uses system information) - Dynamically weighted based on congestion information
- Continuous Analysis can trigger response

Conclusion

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- Infrastructure for analyzing run-time system monitoring data and providing it to applications and system services
  - Improved task placement and work distribution
- In situ analysis
  - Higher frequency data for analysis
    - Need not be stored by the monitoring system
  - Low latency on-node access to results
  - Trigger events based on continuous analysis
  - Global data for decision making
  - Privileged data
- Analysis questions:
  - Characterize the impact of contention measures on performance to refine the weighting
  - Determine the effectiveness of response
  - Aries adaptive routing