TCIPG

GridStat Middleware Communication Framework: Systematic Adaptation

Rate-Based Failure Detection for Mission-Critical Data Delivery

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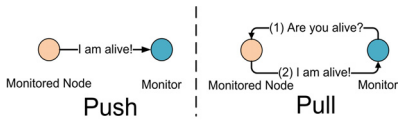
GOALS

- Enhance the resilience of wide-area power applications to both malicious cyber-attacks and benign IT failures through systematic, dynamically adjustable, and extensible (GridStat) adaptation capabilities that respond quicker and with high accuracy.
- Minimize the impact of adaptation ancillary services (instrumentation, failure detection) on core data delivery functionality by exploiting GridStat's rate-based semantics and complete knowledge of sensor flows at every location.

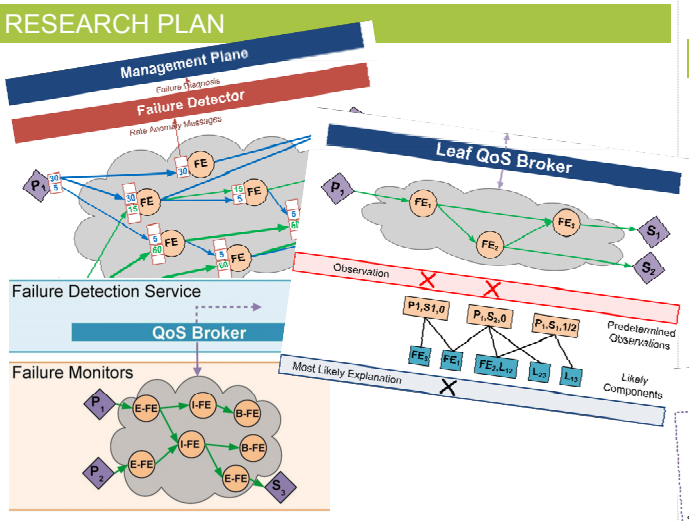
FUNDAMENTAL QUESTIONS/CHALLENGES

- How to continuously maintain stringent QoS+ (low latency, high availability, rate, #paths) guarantees under adaptation with high assurance.
- Making fundamental design choices that have minimum instrumentation, failure detection, and adaptation footprints on the core data delivery guarantees and functionality.
  - Deciding on the appropriate level of instrumentation that is necessary to *accurately* and *sufficiently* capture the state of the data delivery network under changing conditions with the lowest performance penalties.

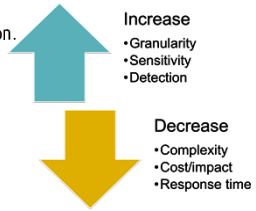


  - Minimizing the total response time of adaptation (detection → diagnosis → identification) of an anomaly to trigger appropriate remedies in a timely fashion.
- Striking a principled balance between *"over adapting,"* which adversaries can try to exploit, and *"under adapting,"* which would affect delivery guarantees of most critical power applications.

RESEARCH PLAN



- A three-pronged monitoring approach to failure detection that fully exploits GridStat's rate-based semantics:
  - **Heartbeat Failure Detection**
    - Used for link/node crash failure detection.
  - **Subscriber QoS Failure Detection**
    - Used for subscriber end QoS (latency, rate) failure detection.
  - **Rate-based Failure Detection**
    - Used for in-network crash and QoS (latency, rate) failure detection.



- A two-tier architectural design: *Monitors* in the GS data plane observing individual flows for faults, *Service Logic* in the management plane.
- Use of *Exponential Weighted Moving Average* (EWMA) to monitor flow packet interval for abnormalities.

RESEARCH RESULTS

- Techniques for localized and continual detection for rate anomalies (both under- and over-rate events) in rate-based data delivery.

EWMA Experiments

- Raw data from a normal distribution with $\mu = 33$ and $\sigma = 2$
- EWMA

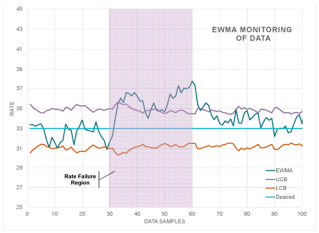
$$ave_k = \alpha * sample_k + (1-\alpha) * ave_{k-1}$$

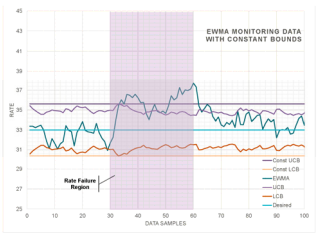
- EWMA standard deviation

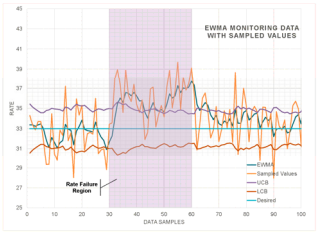
$$\sigma_k = \beta * (sample_k - ave_k) + (1-\beta) * \sigma_{k-1}$$

- Bounds

$$Bound = ave_k \pm Z * \sigma_k * \left(\sqrt{\frac{\alpha}{1-\alpha}}\right)$$







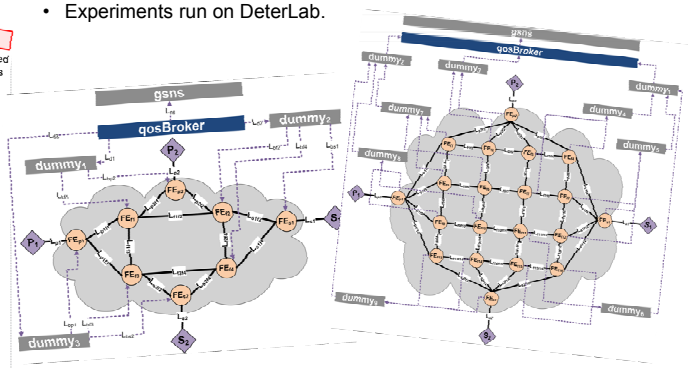
EWMA successfully detects rate anomalies in real-time.

BROADER IMPACT

- Improves the resiliency of mission-critical data delivery for wide-area power applications.
- The novelty and the uniqueness of the rate-based failure detection concept.

INTERACTION WITH OTHER PROJECTS

- Experiments run on DeterLab.



FUTURE EFFORTS

- Development of the adaptation service for GridStat using failure detection input.
- Scalability testing using large-scale experiments involving ~150 nodes.
- Performance analysis of adaptation on GS topologies over real-world bus systems.

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