Title
Scalable Multi-Resolution Storage and Search in Sensor Networks

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Scalable Multi-resolution Storage and Search in Sensor Networks

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Can we use existing data handling architectures for wireless sensor networks?

Typical sensor nodes have limited storage capacity

| Application          | Expected Time to Storage Limit
<table>
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<tbody>
<tr>
<td></td>
<td>if all raw data were stored</td>
</tr>
<tr>
<td>Mines</td>
<td>Months</td>
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<tr>
<td>Spats</td>
<td></td>
</tr>
<tr>
<td>Habitat Monitoring</td>
<td>Few months</td>
</tr>
<tr>
<td>Building Health Monitoring</td>
<td>Few days</td>
</tr>
<tr>
<td>Contaminant Flow</td>
<td>Few months</td>
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<tr>
<td></td>
<td>Few years</td>
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Requirements for Scientific Apps

• Long-term deployment, therefore optimized use of energy and storage resources.
• Flexible search for spatio-temporal features.

Existing Techniques are insufficient

• Centralized data collection is too expensive, while in-network storage capacity is limited (left).
• Existing distributed storage and search systems do not exploit spatio-temporal correlations (right).

Need efficient data reduction, multi-scale data processing, and distributed resource sharing

Exploit Scale

Large-scale sensor network deployments offer a significant distributed storage pool, even though individual sensor nodes have limited local storage. Resources should be used effectively to enable long-term deployment.

Approximate Query Processing

Exact query processing is often expensive. In order to be energy efficient, the system should provide statistically accurate responses, which can be obtained at lower cost.

Exploit Spatio-Temporal Correlation

In a dense sensor network, significant correlation can be expected and should be exploited to reduce storage and communication requirements.

Gracefully Degrading Query Quality

Degrade quality gracefully over time. Accurate responses to queries on recent data can be used to trigger data collection, and time-critical operations. Less accurate responses to queries on older data can be used to understand data trends over time.

Multi-Scale processing

Events exist at certain spatio-temporal scales, for instance, an edge can have a steep or slow gradient. Therefore, the system should support data interpretation over different scales, to extract information from data.

DIMENSIONS: A wavelet-based system for distributed, progressive storage and search

Hierarchical Summarization

• Construct hierarchy of losty wavelet-compressed summaries.
• Queries “drill-down” from root of hierarchy to focus search on small portions of the network.

Progressive Aging

• Progressively age summaries along spatio-temporal hierarchy for long-term storage. Retain summaries based on their utility for query processing and their compactness.
• How do we determine utility of summaries before a system is deployed?
  – Use training datasets available from prior deployments or initial data collection. Solve constraint-optimization problem to determine aging parameters for summaries.
  – Use greedy heuristic that weights summaries depending on expected importance to query processing.

Distributed Resource Allocation

• Construct distributed quad-tree.
  – based on previous work: Geographic Hash Tables (Ratnasamy’02), Greedy Perimeter Stateless Routing (Karp’00)
• Balance storage load by periodically picking different cluster-heads at each level of hierarchy.

Excellent query quality is obtained over most queries with sufficient drill-down levels.

Training performs within 1% of optimal.
• Greedy performs well for appropriate choice of weight parameter.

Near-uniform storage load-sharing is achieved by periodic cluster-head rotation on uniform topologies.