Why do Internet services fail, and what can be done about it?

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Motivation

- Internet service availability is important
  - email, instant messenger, web search, e-commerce, ...

- User-visible failures are relatively frequent
  - especially if use non-binary definition of “failure”

- To improve availability, must know what causes failures
  - know where to focus research
  - objectively gauge potential benefit of techniques

- Approach: study failures from real Internet svcs.
  - evaluation includes impact of humans & networks
Outline

• Describe methodology and services studied

• Identify most significant failure root causes
  - source: type of component
  - impact: number of incidents, contribution to TTR

• Evaluate HA techniques to see which of them
  would mitigate the observed failures

• Drill down on one cause: operator error

• Future directions for studying failure data
Methodology

- Obtain “failure” data from three Internet services
  - two services: problem tracking database
  - one service: post-mortems of user-visible failures
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  - one service: post-mortem of user-visible failures

• We analyzed each incident
  - failure root cause
    » hardware, software, operator, environment, unknown
  - type of failure
    » “component failure” vs. “service failure”
  - time to diagnose + repair (TTR)
Methodology

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  - one service: post-mortems of user-visible failures

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  - type of failure
    » “component failure” vs. “service failure”
  - time to diagnose + repair (TTR)

• Did not look at security problems
## Comparing the three services

<table>
<thead>
<tr>
<th>characteristic</th>
<th>Online</th>
<th>ReadMostly</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>hits per day</td>
<td>~100 million</td>
<td>~100 million</td>
<td>~7 million</td>
</tr>
<tr>
<td># of machines</td>
<td>~500 @ 2 sites</td>
<td>&gt; 2000 @ 4 sites</td>
<td>~500 @ ~15 sites</td>
</tr>
<tr>
<td>front-end node architecture</td>
<td>custom s/w; Solaris on SPARC, x86</td>
<td>custom s/w; open-source OS on x86</td>
<td>custom s/w; open-source OS on x86</td>
</tr>
<tr>
<td>back-end node architecture</td>
<td>Network Appliance filers</td>
<td>custom s/w; open-source OS on x86</td>
<td>custom s/w; open-source OS on x86</td>
</tr>
<tr>
<td>period studied</td>
<td>7 months</td>
<td>6 months</td>
<td>3 months</td>
</tr>
<tr>
<td># component failures</td>
<td>296</td>
<td>N/A</td>
<td>205</td>
</tr>
<tr>
<td># service failures</td>
<td>40</td>
<td>21</td>
<td>56</td>
</tr>
</tbody>
</table>
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  - **source**: type of component
  - **impact**: number of incidents, contribution to TTR

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Failure cause by % of service failures

**Online**
- Operator: 33%
- Network: 20%
- Software: 25%
- Hardware: 10%
- Unknown: 12%

**Content**
- Operator: 36%
- Network: 15%
- Software: 25%
- Hardware: 2%
- Unknown: 22%

**ReadMostly**
- Operator: 19%
- Network: 62%
- Software: 5%
- Unknown: 14%
Failure cause by % of TTR

**Online**
- unknown: 1%
- hardware: 6%
- software: 17%
- network: 1%
- operator: 76%

**Content**
- software: 6%
- network: 19%
- operator: 75%

**ReadMostly**
- operator: 3%
- network: 97%
Most important failure root cause?

• **Operator error generally the largest cause of service failure**
  - even more significant as fraction of total “downtime”
  - configuration errors > 50% of operator errors
  - generally happened when making changes, not repairs

• **Network problems significant cause of failures**
Related work: failure causes

• Tandem systems (Gray)
  - 1985: Operator 42%, software 25%, hardware 18%
  - 1989: Operator 15%, software 55%, hardware 14%

• VAX (Murphy)
  - 1993: Operator 50%, software 20%, hardware 10%

• Public Telephone Network (Kuhn, Enriquez)
  - 1997: Operator 50%, software 14%, hardware 19%
  - 2002: Operator 54%, software 7%, hardware 30%
Outline

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  – source: type of component
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• Future directions for studying failure data
### Potential effectiveness of techniques?

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<th>Technique</th>
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<tr>
<td>post-deployment correctness testing*</td>
</tr>
<tr>
<td>expose/monitor failures*</td>
</tr>
<tr>
<td>redundancy*</td>
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<tr>
<td>automatic configuration checking</td>
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<tr>
<td>post-deploy. fault injection/load testing</td>
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<tr>
<td>component isolation*</td>
</tr>
<tr>
<td>pre-deployment fault injection/load test</td>
</tr>
<tr>
<td>proactive restart*</td>
</tr>
<tr>
<td>pre-deployment correctness testing*</td>
</tr>
</tbody>
</table>

* indicates technique already used by Online
## Potential effectiveness of techniques?

<table>
<thead>
<tr>
<th>technique</th>
<th>failures avoided / mitigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>post-deployment correctness testing*</td>
<td>26</td>
</tr>
<tr>
<td>expose/monitor failures*</td>
<td>12</td>
</tr>
<tr>
<td>redundancy*</td>
<td>9</td>
</tr>
<tr>
<td>automatic configuration checking</td>
<td>9</td>
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<tr>
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<td>6</td>
</tr>
<tr>
<td>component isolation*</td>
<td>5</td>
</tr>
<tr>
<td>pre-deployment fault injection/load test</td>
<td>3</td>
</tr>
<tr>
<td>proactive restart*</td>
<td>3</td>
</tr>
<tr>
<td>pre-deployment correctness testing*</td>
<td>2</td>
</tr>
</tbody>
</table>

(40 service failures examined)
Outline

• Describe methodology and services studied

• Identify most significant failure root causes
  - source: type of component
  - impact: number of incidents, contribution to TTR

• Evaluate existing techniques to see which of them would mitigate the observed failures

• Drill down on one cause: operator error

• Future directions for studying failure data
Drilling down: operator error

Why does operator error cause so many svc. failures?

% of component failures resulting in service failures

Existing techniques (e.g., redundancy) are minimally effective at masking operator error
Drilling down: operator error TTR

Why does operator error contribute so much to TTR?

Detection and diagnosis difficult because of non-failstop failures and poor error checking

Online
- unknown: 1%
- hardware: 6%
- software: 17%
- network: 1%

Content
- software: 6%
- network: 19%
- operator: 75%

operator: 76%
Future directions in studying failures

• Quantify impact of operational practices

• Study additional types of sites
  - transactional, intranets, peer-to-peer

• Create a public failure data repository
  - standard taxonomy of failure causes
  - standard metrics for impact
  - techniques for automatic anonymization
  - security (not just reliability)
  - automatic analysis (mining for trends, fixes, attacks, ...)

• Perform controlled laboratory experiments
Conclusion

• Operator error large cause of failures, downtime

• Many failures could be mitigated with
  - better post-deployment testing
  - automatic configuration checking
  - better error detection and diagnosis

• Longer-term: concern for operators must be built into systems from the ground up
  - make systems robust to operator error
  - reduce time it takes operators to detect, diagnose, and repair problems
Willing to contribute failure data, or information about problem detection/diagnosis techniques?

http://roc.cs.berkeley.edu/projects/faultmanage/

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