Overview

- Slow builds impact almost all medium/large development teams

- Electric Cloud speeds up builds 10-20x:
  - Harnesses clusters of inexpensive servers
  - Unlocks concurrency by deducing dependencies
  - Minimizes scalability bottlenecks

- Faster builds mean
  - Faster time to market
  - Higher product quality
  - Ability to do more with less
Outline

- The impact of slow builds
- The holy grail: concurrent builds
- Dependencies: problem and solution
- Electric Cloud architecture
- Managing files
- Limiting bottlenecks
- Performance measurements
Problem: Slow Builds

Over 500 companies surveyed, average build 2-4 hours

5-15% loss in engineering productivity:
- Wasted engineering time & frustration
- Less time to fix bugs, add features

5-10% delay in time to market:
- Slow builds add weeks to release cycles
- Uncertainty & risk due to last-minute broken builds

Quality & customer satisfaction:
- Developers can’t rebuild before check-in
- QA waiting on broken builds or skipping tests to meet deadlines
- More bugs escape to the field
Personal Experience

Slow builds drove me crazy

- Sprite research project (Berkeley, late ’80s):
  - Most popular feature was “pmake”
  - Painful to return to traditional OS
- Interwoven, 2000-2001:
  - 7-10-hour builds
  - > 1 month with no successful daily builds, late in a release cycle

Discovered that they drive everyone crazy!

Founded Electric Cloud to solve the problem
Theoretical Solution: Concurrency

- Builds have inherent parallelism
- Solution: split up builds and run pieces concurrently
  - Large SMP Machines (gmake –j)
  - Distributed builds (distcc)

If only it were this easy…
Problem: Dependencies

- Builds have inherent parallelism
- Solution: split up builds and run pieces concurrently
  - Large SMP Machines (gmake -j)
  - Distributed builds (distcc)
- Current attempts to speed builds yield small results
- Dependency problems:
  - Incomplete
  - Can’t be expressed between Makefiles
  - Result: broken builds

Difficult to get more than a 2-3x speedup
Hard to maintain Makefiles
Deduce dependencies on-the-fly:
- Watch all file accesses: these indicate dependencies
- Automatically detect out-of-order steps

Desired

Actual

Run in parallel? Error!
Deduce dependencies on-the-fly:
- Watch all file accesses: these indicate dependencies
- Automatically detect and correct out-of-order steps
- Save discovered dependencies for future builds
- Result: high concurrency possible

**Desired**

- Link library
  - write: `01010101 01010101 01010101 01010101`
  - read
- Link app.

**Actual**

- Link library
  - read: `10101010 10101010 10101010 10101010 10101010 10101010 10101010`
  - write: `01010101 01010101 01010101 01010101 01010101 01010101 01010101`
- Link app.

**Discard**

- Old:
  - x.lib

**Rerun**

- Link library
  - read
- Link app.
Electric Cloud Architecture

Cluster Manager

Make Machine
Electric Make

Network

Manager
Cluster Manager

Lightweight Electric Node
Agent

Electric File System

Inexpensive rack-mounted servers run pieces of build in parallel

Web-based reporting, management tools

Plug-in replacement for GNU Make, Microsoft NMAKE
Clustering Approach

Advantages (vs. multiprocessor):
- Cost-effective: $1-2K per CPU
- Scalable: no hard limit to cluster size

Potential problems:
- Build state not necessarily available on nodes
- Overhead for network communication
- Robustness: more pieces that can break
Virtualization

- Node environment must duplicate make machine; hard because of
  - ClearCase views
  - Different environments on different make machines
  - File versioning within a build

- Simple application-specific network file system:
  - Electric Make is server
  - Agent is client, fetches files on demand
  - Virtualizes subtree(s) from make machine
  - Files cached on nodes during a build

- On Windows, registry data is also virtualized on nodes
Files can have many versions during build:
- Append to log file
- Debug/release versions compiled to same .o files

Each read must return correct version (based on sequential order for build)

Electric Make maintains version history for each file
- Tricky: name space must be versioned also

Network file system passes appropriate version to each job, flushes caches when necessary
Network Optimization

P2P file transfers offload 20-25% of outbound traffic:
- Take advantage of inexpensive bandwidth within switch

Just-in-time compression cuts traffic 2.5-3x:
- Match network bandwidth to disk
Highly parallel builds stress build machine’s file system:
- Average bandwidth as high as 10-20 MB/s
- ClearCase? High latency

All disk I/O passes through Electric Make: opportunity to manage read & write concurrency
- Single disk? Concurrency causes extra head motion
- Network file system? More concurrency hides network latency

Metadata caching improves ClearCase performance significantly
Recursive Makes

**Gmake:** separate gmake invocation for each Makefile:
- Hard to extract & manage concurrency
- Can’t manage dependencies across Makefile

**Electric Make:** merge Makefiles
- Recursive makes return immediately with parameter info
- Top-level emake manages multiple make instances
Compatibility

Plug-compatible with GNU Make, Microsoft NMAKE, Sun make

- Change ‘gmake’ or ‘nmake’ to ‘emake’ in build scripts
- Identical command-line options
- Identical results (except builds run faster)
- Identical log file output
- Typically a few Makefile changes to maximize speedup
Manageability

- Web-based administration
  - As easy to manage many nodes as 1 node

- Can be used by entire team:
  - Supports multiple simultaneous builds
  - Priority system for node allocation

- Robust: automatic fail-over on node failures
Results: Open Source

<table>
<thead>
<tr>
<th></th>
<th>Local</th>
<th>20 CPUs</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samba</td>
<td>952s</td>
<td>58s</td>
<td>16.4x</td>
</tr>
<tr>
<td>MySQL</td>
<td>1400s</td>
<td>124s</td>
<td>11.3x</td>
</tr>
<tr>
<td>Gtk</td>
<td>891s</td>
<td>95s</td>
<td>9.4x</td>
</tr>
</tbody>
</table>

Evaluation notes were added to the output document. To get rid of these notes, please order your copy of ePrint IV now.
Results: Linux Kernel

- Linux Kernel 2.6.1
- Make bzimage + modules
- 2.8 GHz Xeon, 1 GB RAM, IDE Drive

<table>
<thead>
<tr>
<th></th>
<th>Build Time [mm:ss]</th>
<th>Speedup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>22:08</td>
<td></td>
</tr>
<tr>
<td>5 nodes</td>
<td>5:09</td>
<td>4.3x</td>
</tr>
<tr>
<td>10 nodes</td>
<td>2:40</td>
<td>8.3x</td>
</tr>
<tr>
<td>15 nodes*</td>
<td>2:03</td>
<td>10.8x</td>
</tr>
<tr>
<td>20 nodes*</td>
<td>1:42</td>
<td>13.0x</td>
</tr>
</tbody>
</table>

* Projected build time

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Impact: 3 week savings out of an 8 month release cycle expected
Solaris 2.8

<table>
<thead>
<tr>
<th>Build Time (minutes)</th>
<th>GNU Make</th>
<th>Electric Cloud (30 nodes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>274</td>
<td>0:13</td>
</tr>
</tbody>
</table>

Impact: Enabled worldwide follow-the-sun development
We eat our own dog food

**Continuous build system:**
- Start build and test cycle whenever changes are committed to the main branch
What about distcc?

- Works with gmake -j
- Distributes compile steps to nodes
- Preprocesses code on make machine:
  - Preprocessed code is self-contained: eliminates virtualization issues
### distcc vs. Electric Cloud

**distcc:**
- Free
- Works with other build tools (SCons?)
- Portable
- Compiler-specific (gcc)
- Less scalable:
  - Only distributes compiles; preprocessing centralized
  - Missing dependencies break build
- Build log scrambled
- No cluster sharing facilities?

**Electric Cloud:**
- Not free
- Only works with Make
- Windows, Linux, Solaris
- Works with all compilers
- More scalable:
  - Distributes all build steps (even Makefile parsing)
  - Deduces dependencies to avoid build breakage
  - Parallelizes sub-makes
- Build log in sequential order
- Cluster mgmt/sharing
Electric Make vs. Distcc

MySQL

- Electric Make
- GNU make/distcc

Number of Agents

Speedup

distcc breaks build

Mozilla

- Electric Make
- GNU make/distcc

Number of Agents

Speedup

Apache

- Electric Make
- GNU make/distcc

Number of Agents

Speedup

Linux Kernel

- Electric Make
- GNU make/distcc

Number of Agents

Speedup

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Performance Limits

- File system on make machine
  - ClearCase dynamic views particularly slow

- Serializations within builds
  - Linking slow on Linux

- Make machine CPU not an issue
  - Typically running at 30% utilization
### Impact of 10-20x Speedup

<table>
<thead>
<tr>
<th>Build Time</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 hours</td>
<td>Build doesn’t finish overnight</td>
</tr>
<tr>
<td>6 hours</td>
<td>Overnight build</td>
</tr>
<tr>
<td>2 hours</td>
<td>Multiple revs in a single day</td>
</tr>
<tr>
<td>30 min.</td>
<td>Full rebuild before checkin</td>
</tr>
<tr>
<td>5 min.</td>
<td>Little need to switch context</td>
</tr>
<tr>
<td>1 min.</td>
<td>No need to switch context</td>
</tr>
</tbody>
</table>

Electric Cloud can drop you two bands

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No need to tolerate slow builds anymore

Faster builds mean
- Faster time to market
- Higher quality
- Ability to do more with less
For more information or to answer additional questions:

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