10-20x Faster Software Builds

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Overview

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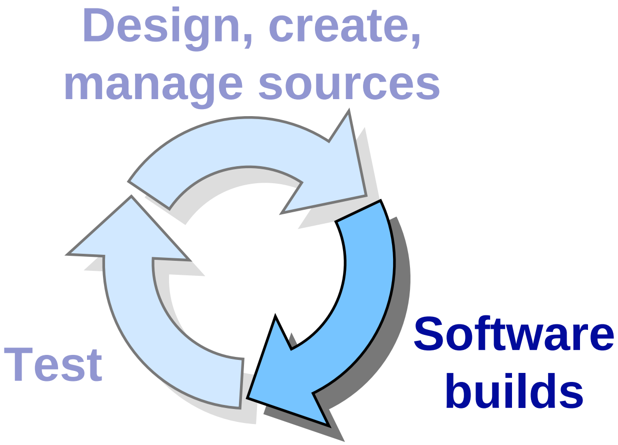
- **Slow builds impact almost all medium/large development teams**
- **Electric Cloud speeds up builds 10-20x:**
  - Harnesses clusters of inexpensive servers
  - Unlocks concurrency by deducing dependencies
  - Minimizes scalability bottlenecks
- **Faster builds mean**
  - Faster time to market
  - 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 commercial OS’es
  - 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

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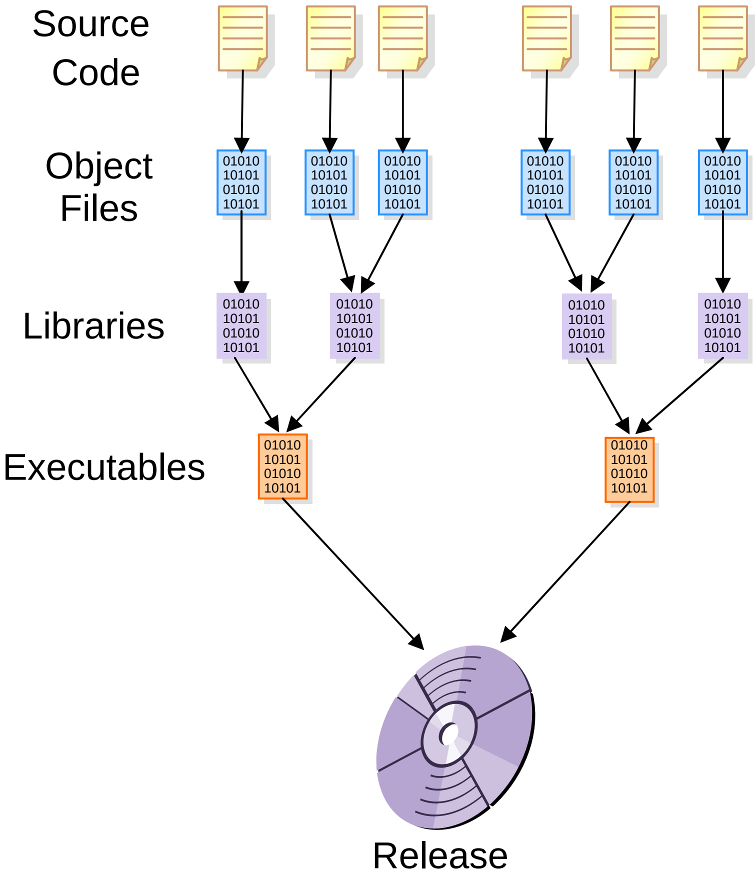
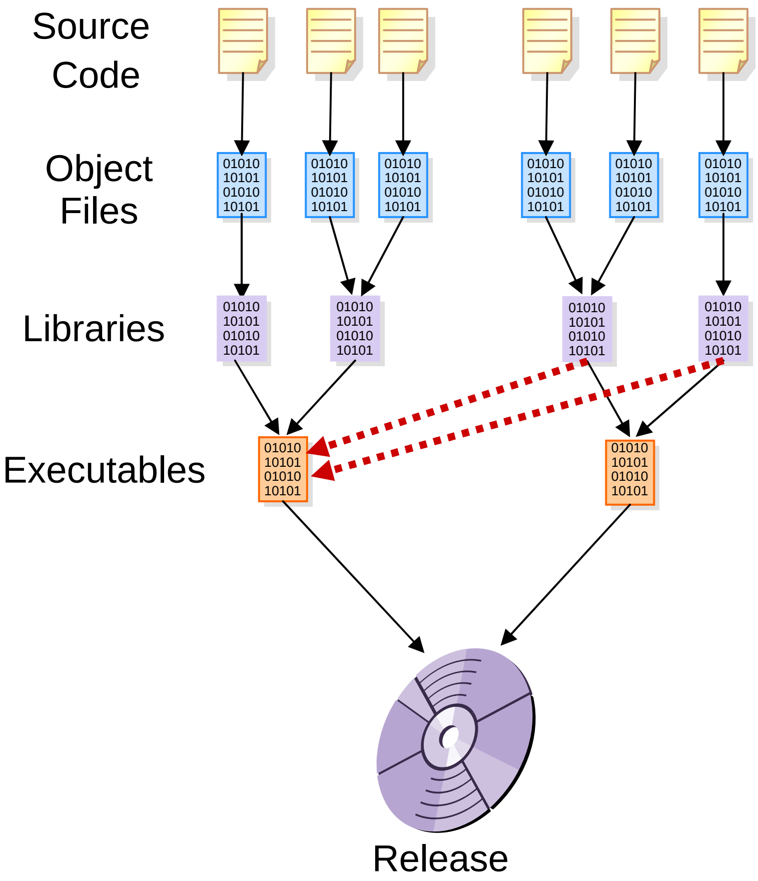


- **Builds have inherent parallelism**
- **Solution: split up builds and run pieces concurrently**
  - Large SMP Machines (gmake –j)
  - Distributed builds (distcc)

If only it were this easy…

Problem: Dependencies



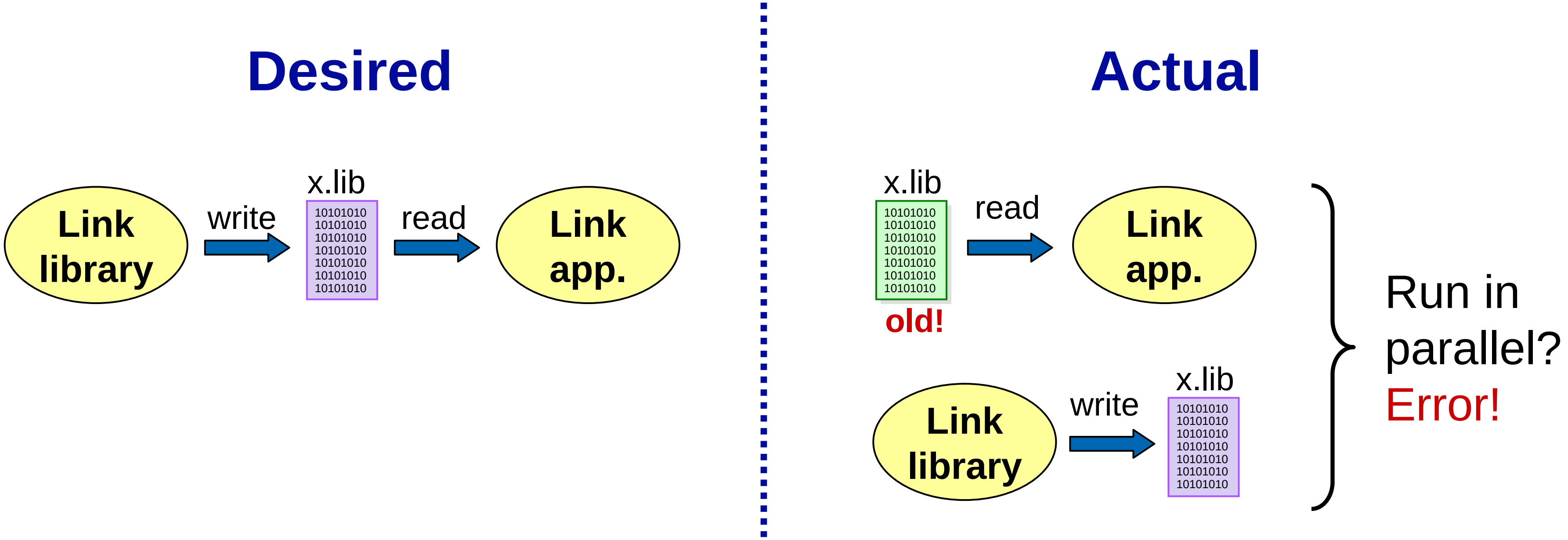
- Builds have inherent parallelism
- Solution: split up builds and run pieces concurrently
  - Large SMP Machines (gmake –j)
  - Distributed builds (distcc)
- **Current attempts to speed builds yield small results**
- **Dependency problems:**
  - Incomplete
  - Can't be expressed between Makefiles
 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

Difficult to get more than a 2-3x speedup

Hard to maintain Makefiles

Electric Cloud Solution

- **Deduce dependencies on-the-fly:**
  - Watch all file accesses: these indicate dependencies
  - Automatically detect out-of-order steps



Desired

Link library → write → x.lib → read → Link app.

Actual

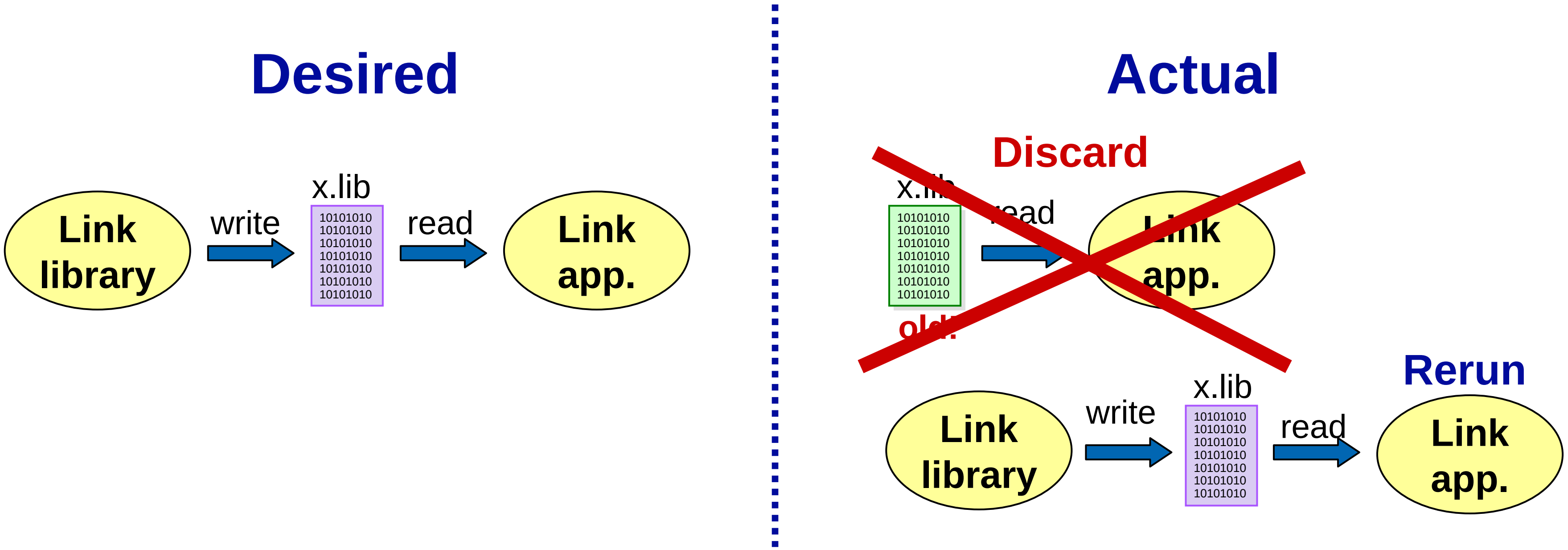
x.lib (old!) → read → Link app.

Link library → write → x.lib

Run in parallel? Error!

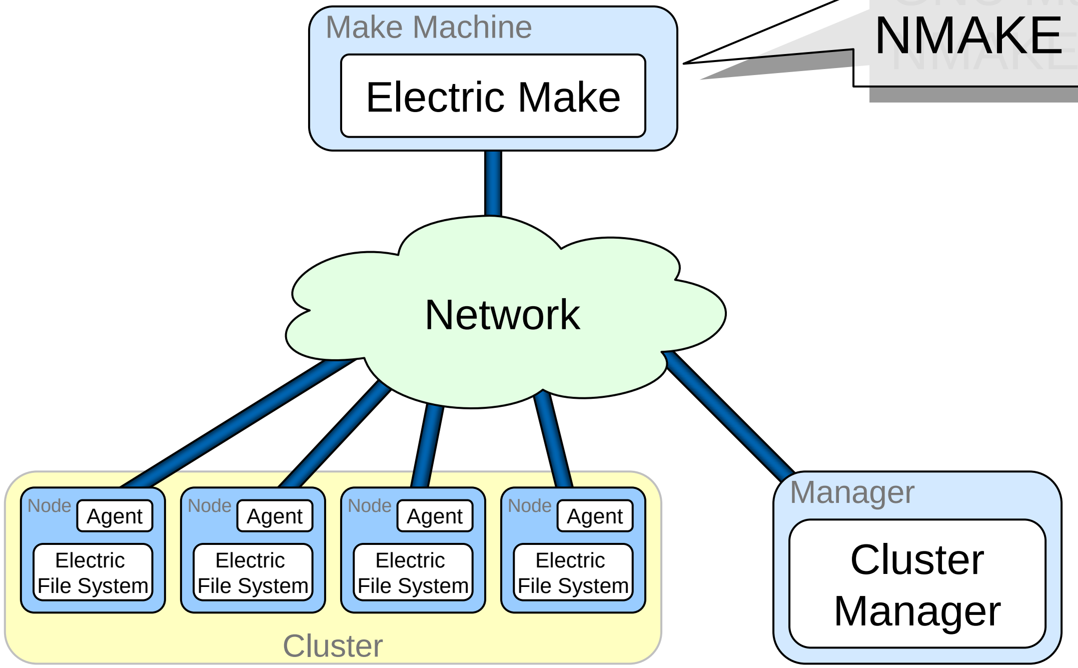
Electric Cloud Solution

- **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



Electric Cloud Architecture

Plug-in replacement for GNU Make, Microsoft NMAKE



Inexpensive rack-mounted servers run pieces of build in parallel

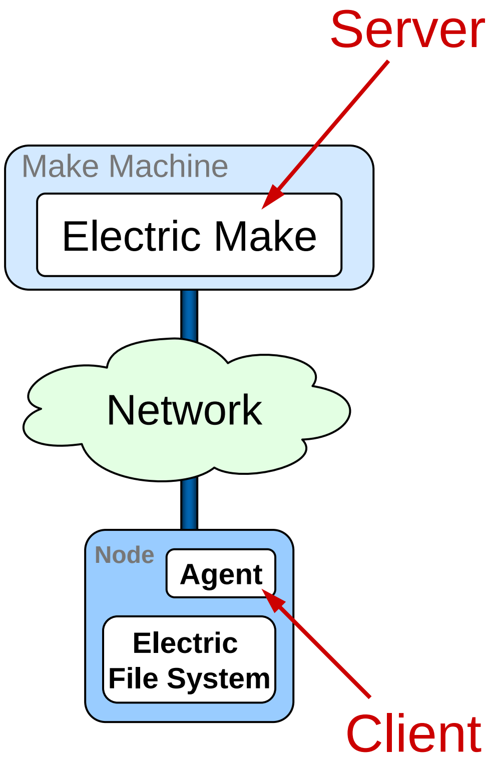
Web-based reporting, management tools

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

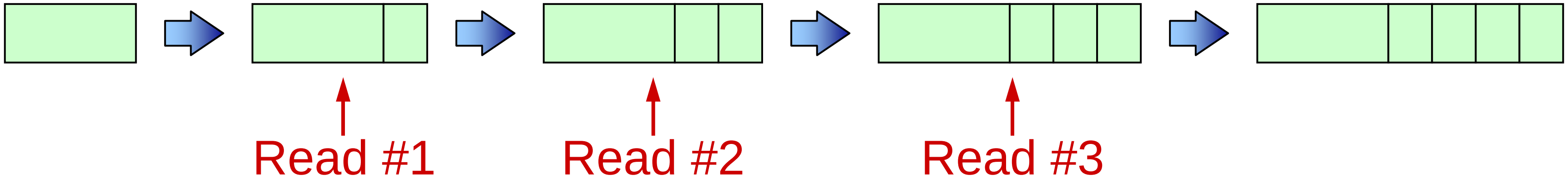
Virtualization

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



Versioning File System

Example: log file extended with series of appends



- **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

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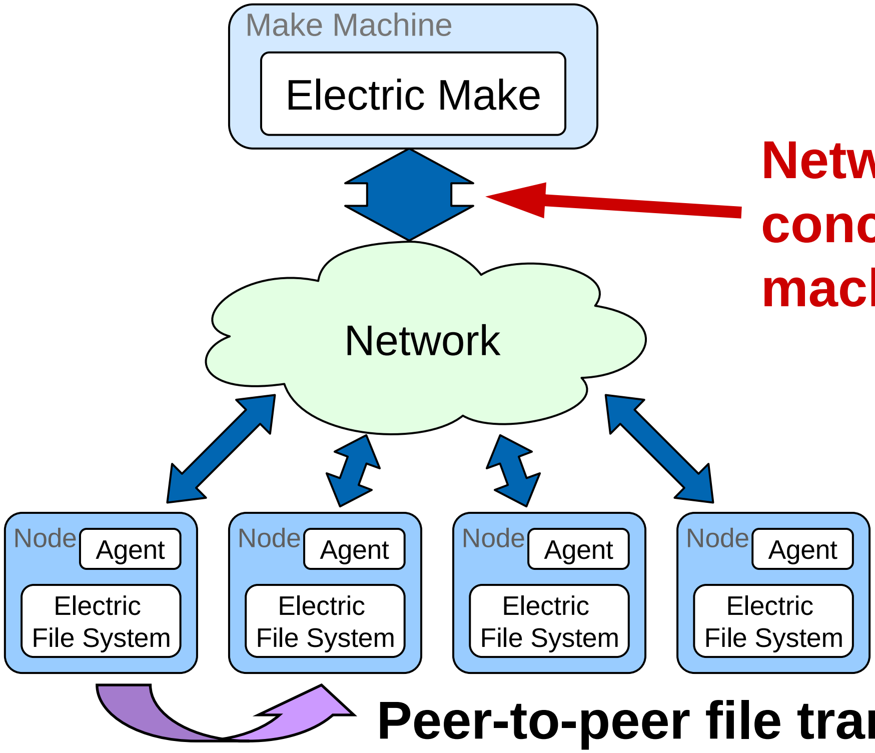


Network bandwidth concentrates at make machine

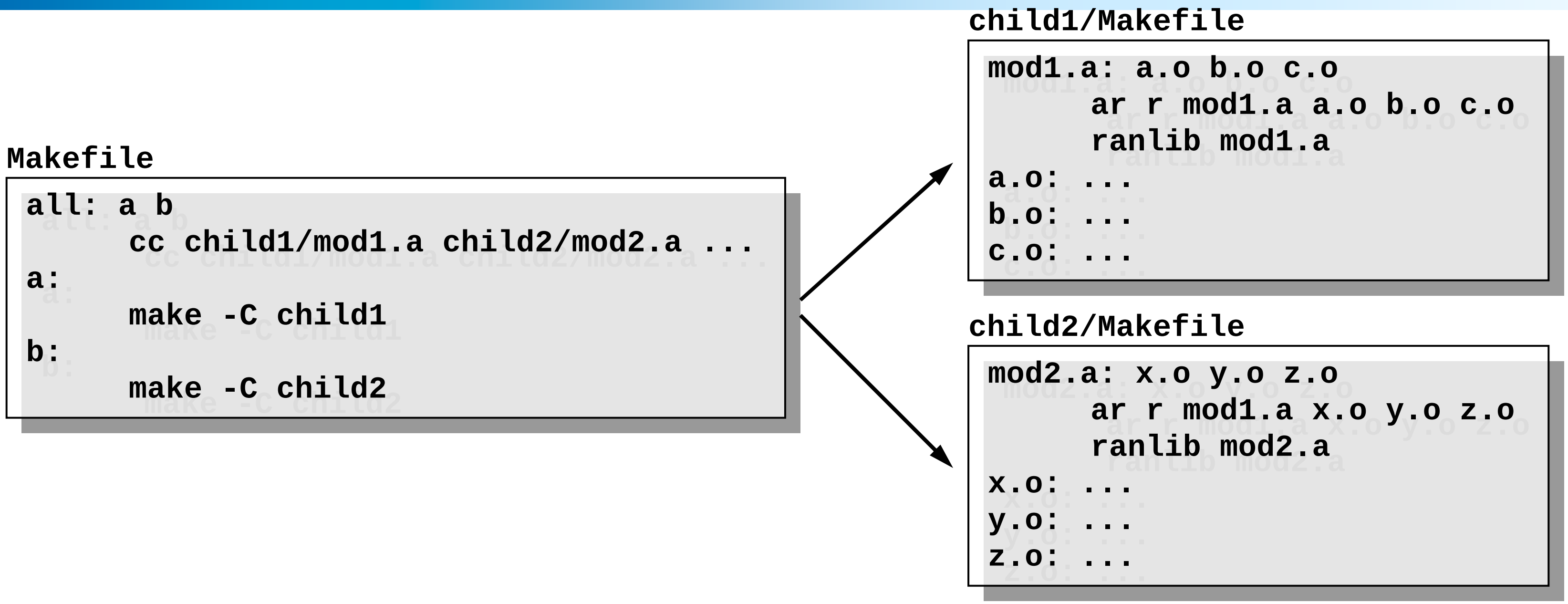
Peer-to-peer file transfer

- **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

File System Optimization

- **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



Makefile

```
all: a b
      cc child1/mod1.a child2/mod2.a ...
a:
      make -C child1
b:
      make -C child2
```

child1/Makefile

```
mod1.a: a.o b.o c.o
      ar r mod1.a a.o b.o c.o
      ranlib mod1.a
a.o: ...
b.o: ...
c.o: ...
```

child2/Makefile

```
mod2.a: x.o y.o z.o
      ar r mod1.a x.o y.o z.o
      ranlib mod2.a
x.o: ...
y.o: ...
z.o: ...
```

- **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*

Recursive Makes, cont’d

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- Where this works well:

```
all:
    for i in “a b c d e f g”; do \
      cd $$i; $(MAKE); cd ..; \
    done
```

- Where this doesn’t work so well (output of submakes is used):

```
all:
    for i in “a b c d e f g”; do \
      cd $$i; $(MAKE) >> log; cd ..; \
    done
```

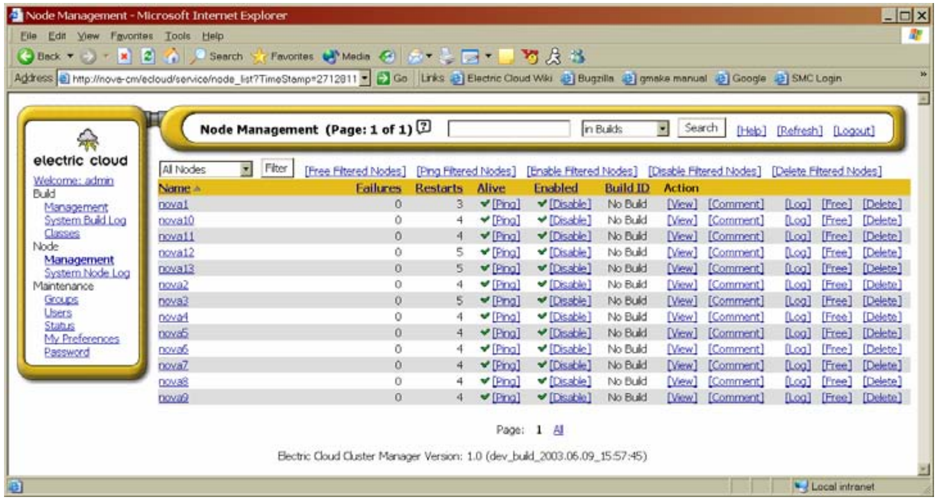
- Must modify Makefiles in some cases

Compatibility

- **Plug-compatible with GNU Make, Microsoft NMAKE:**
  - 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**


Node Management - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://nova-cm/ecloud/service/node_list?TimeStamp=2712811
Go
Links Electric Cloud Wiki Bugzilla gmake manual Google SMC Login
Local intranet

Node Management (Page: 1 of 1)

in Builds | Search | [Help] [Refresh] [Logout]

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Welcome: admin
Build
Management
System Build Log
Classes
Node
Management
System Node Log
Maintenance
Groups
Users
Status
My Preferences
Password

All Nodes | Filter | [Free Filtered Nodes] [Ping Filtered Nodes] [Enable Filtered Nodes] [Disable Filtered Nodes] [Delete Filtered Nodes]

Name	Failures	Restarts	Alive	Enabled	Build ID	Action
nova1	0	3	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]
nova10	0	4	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]
nova11	0	4	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]
nova12	0	5	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]
nova13	0	5	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]
nova2	0	4	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]
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nova4	0	4	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]
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nova8	0	4	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]
nova9	0	4	✓ [Ping]	✓ [Disable]	No Build	[View] [Comment] [Log] [Free] [Delete]

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Electric Cloud Cluster Manager Version: 1.0 (dev_build_2003.06.09_15:57:45)

Results: Open Source

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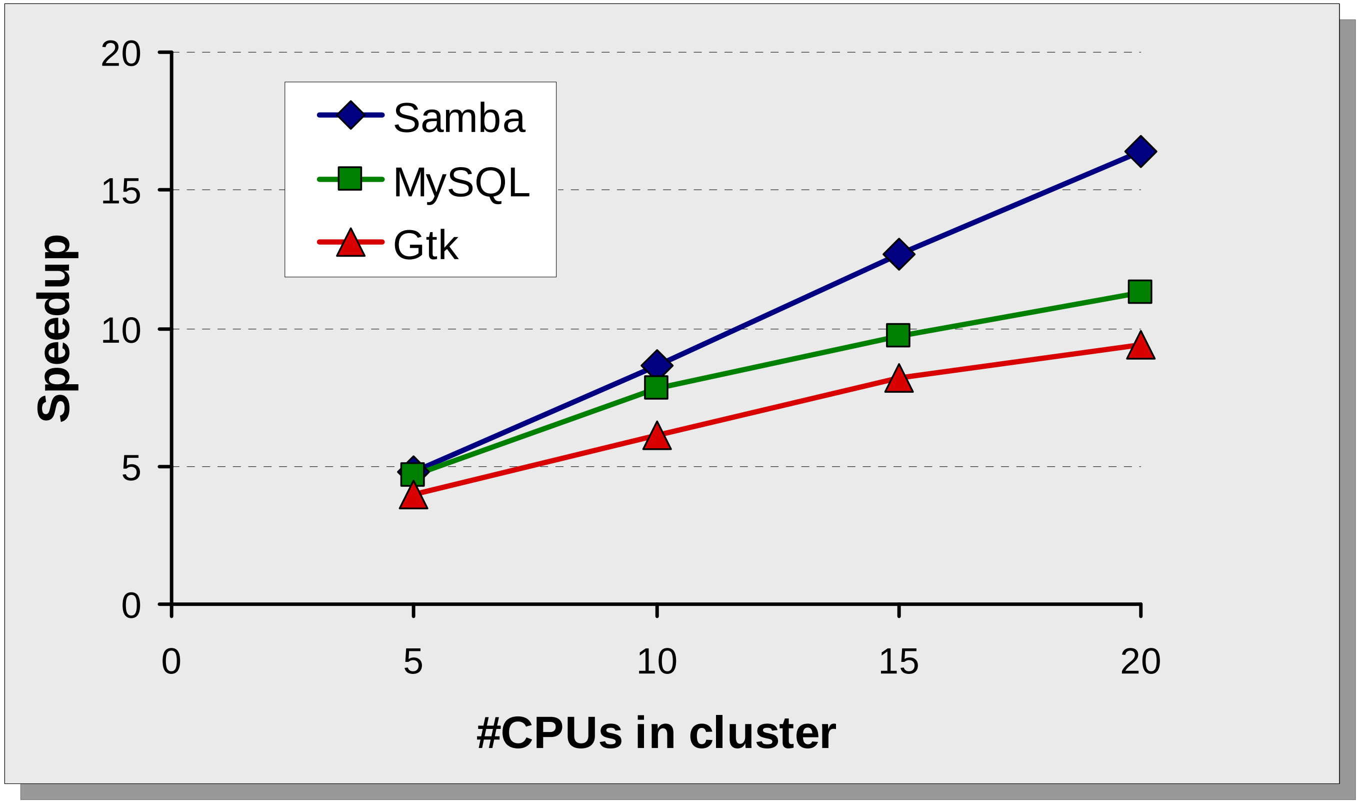
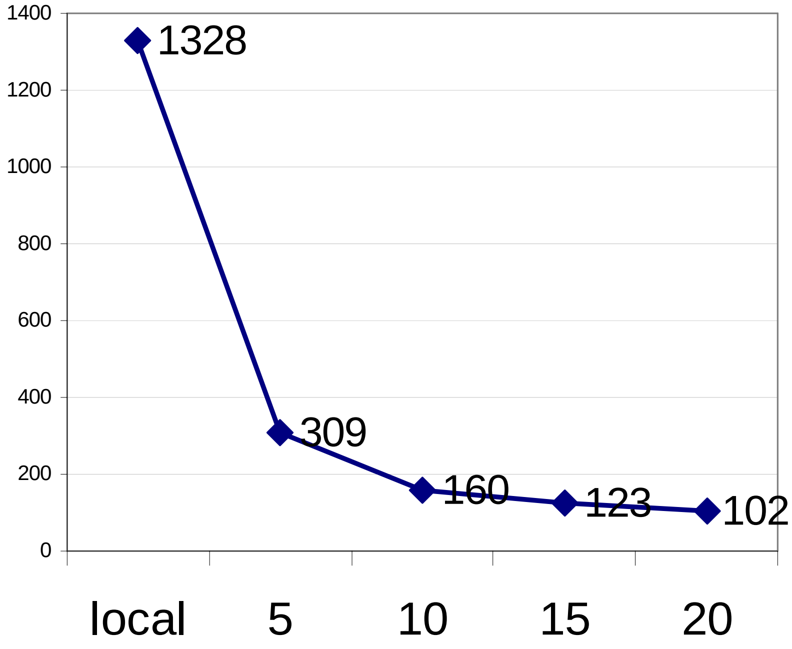


	Local	20 CPUs	Speedup
Samba	952s	58s	16.4x
MySQL	1400s	124s	11.3x
Gtk	891s	95s	9.4x

Results: Linux Kernel

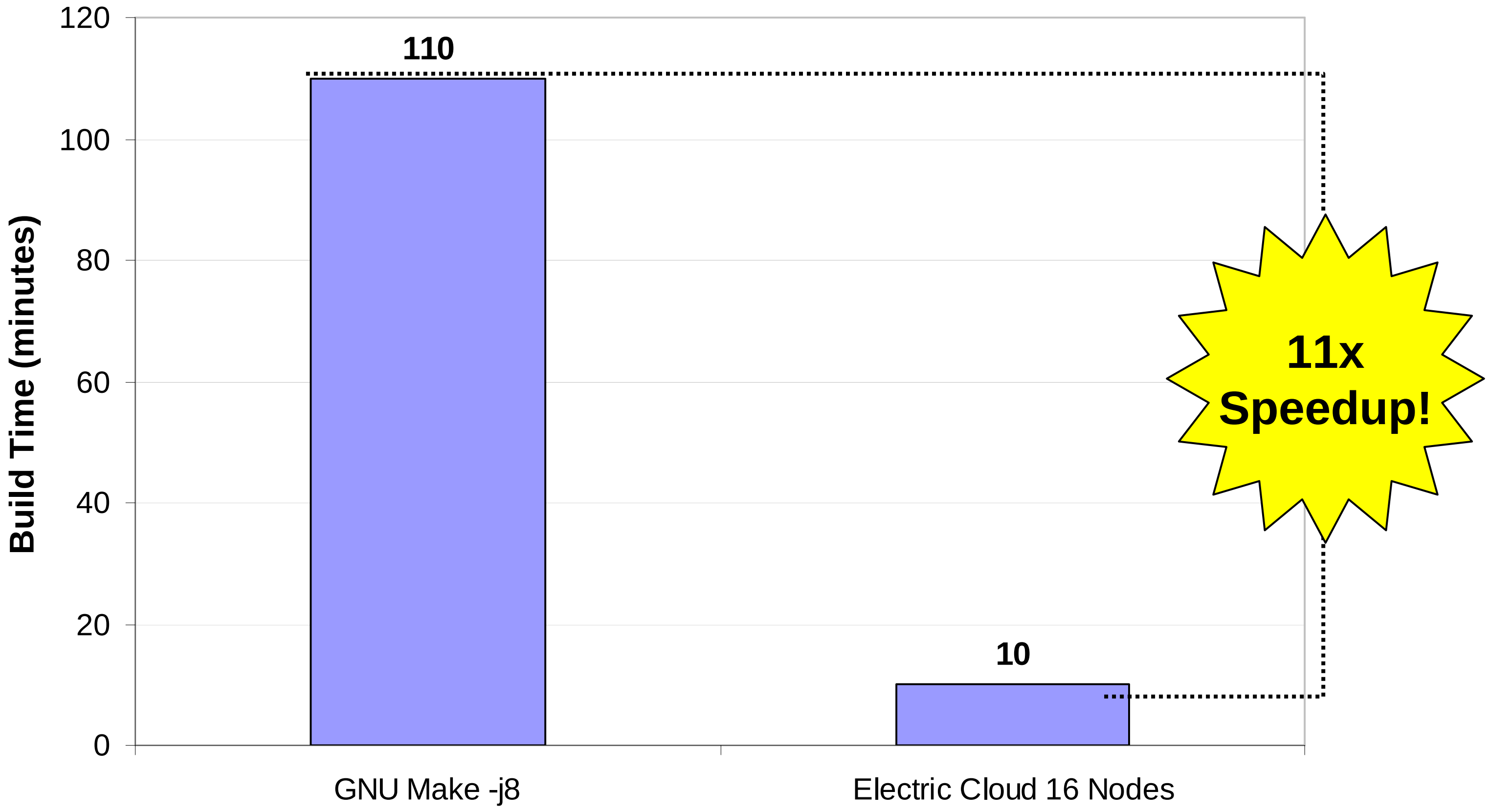
- Linux Kernel 2.6.1
- Make bzimage + modules
- 2.8 GHz Xeon, 1 GB RAM, IDE Drive

	Build Time [mm:ss]	Speedup
Local	22:08	
5 nodes	5:09	4.3x
10 nodes	2:40	8.3x
15 nodes*	2:03	10.8x
20 nodes*	1:42	13.0x



* Projected build time

Telecom Equip. Vendor



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

Enterprise Software Co.

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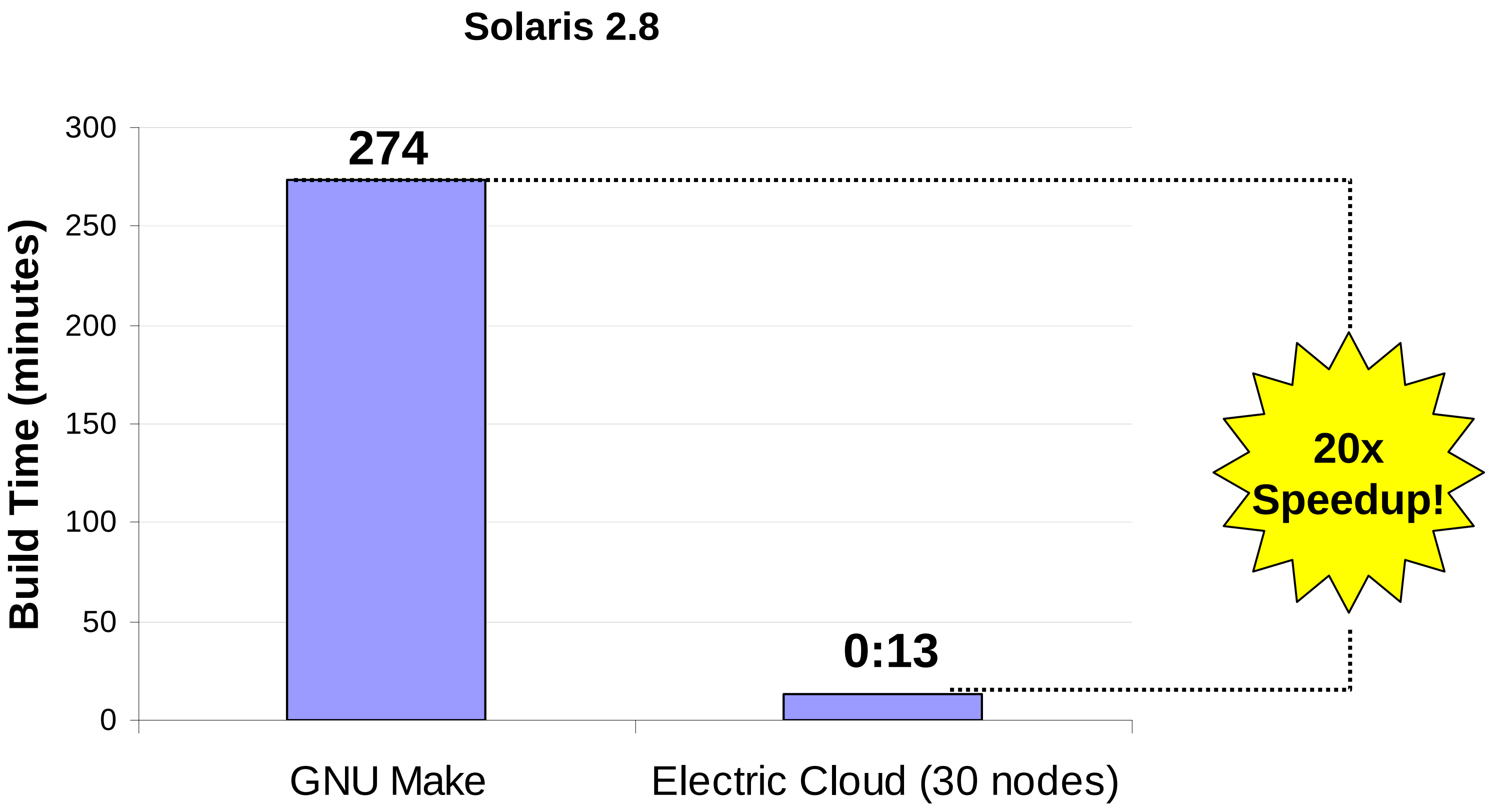
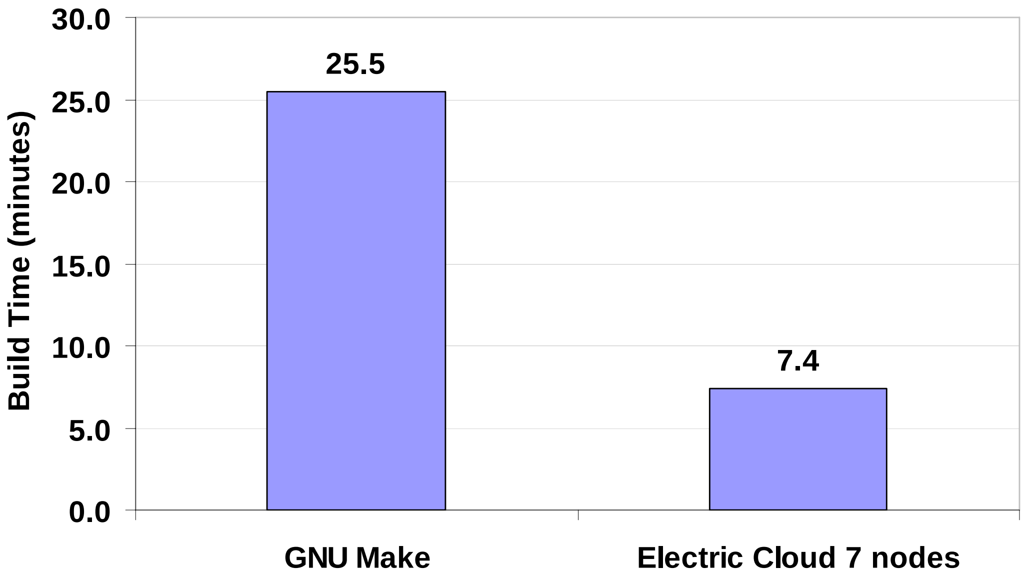


Impact: Enabled worldwide follow-the-sun development

Electric Cloud



- **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

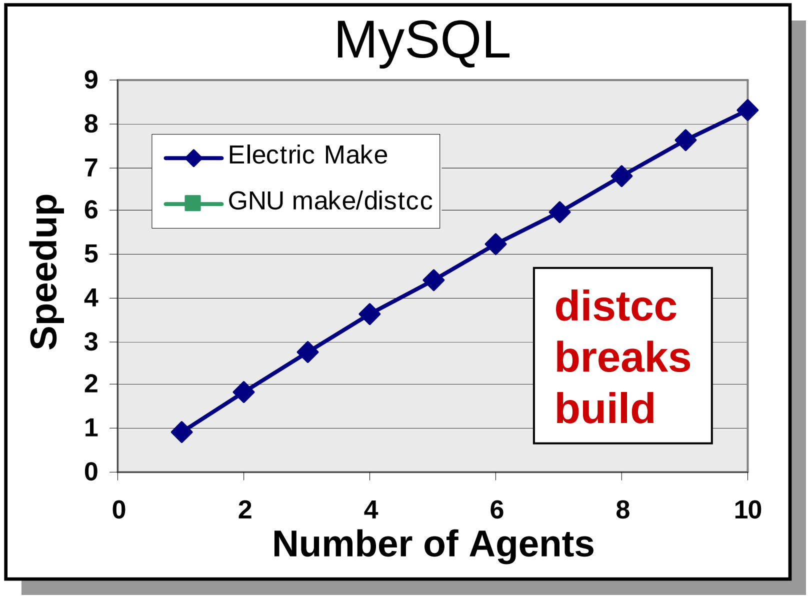
distcc:

- 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?

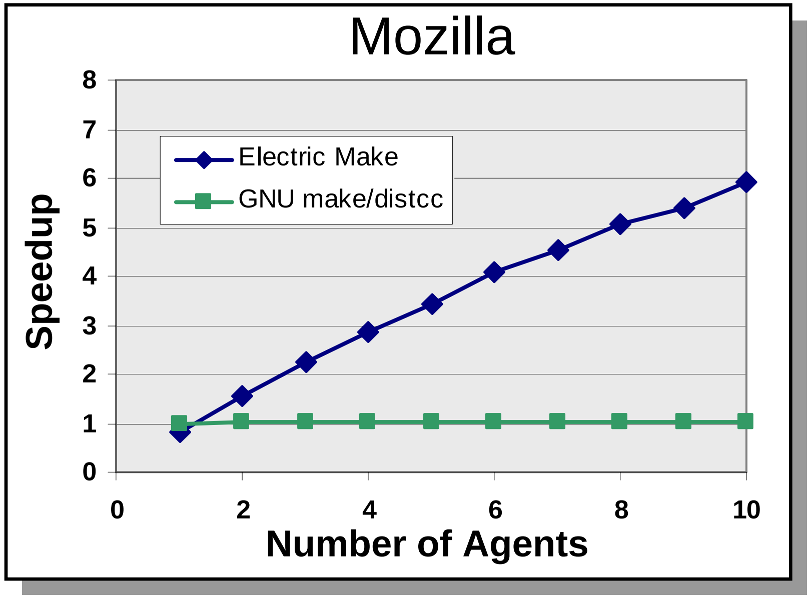
Electric Cloud:

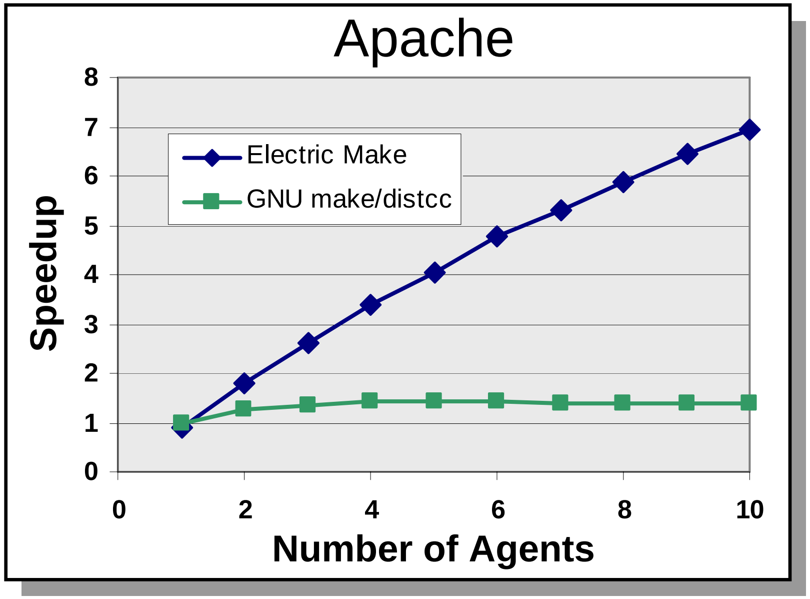
- Not free
- Only works with Make
- Windows, Linux, Solaris
- Works with all compilers
- More scalable:
  - Distributes all build steps (even Makefile parsing)
  - Deduces dependencies to avoid build breakage
  - Parallelizes sub-makes
- Build log in sequential order
- Cluster mgmt/sharing

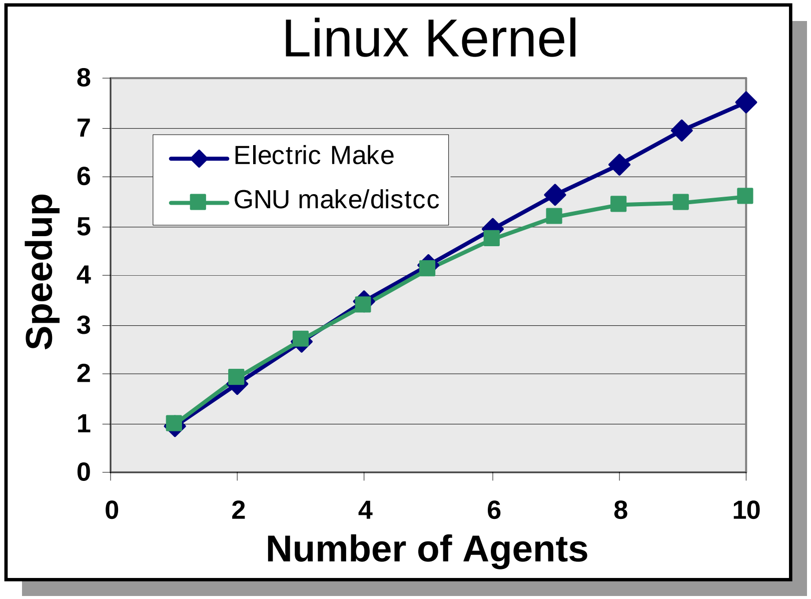
Electric Make vs. Distcc


MySQL

distcc breaks build


Mozilla


Apache

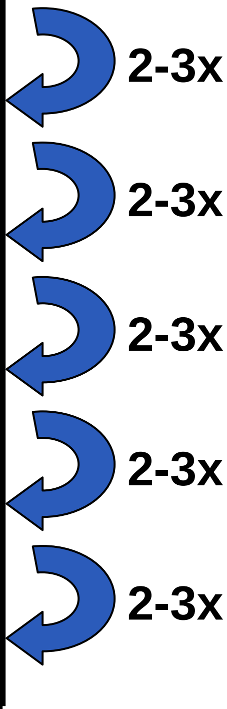

Linux Kernel

Performance Limits

- **File system on make machine**
  - ClearCase dynamic views particularly slow
  - Windows: large .pdb and .pch files
- **Serializations within builds**
  - Linking slow on Linux
- **Make machine CPU not an issue**
  - Typically running at 30% utilization

Impact of 10-20x Speedup

Build Time	Impact
14 hours	Build doesn’t finish overnight
6 hours	Overnight build
2 hours	Multiple revs in a single day
30 min.	Full rebuild before checkin
5 min.	Little need to switch context
1 min.	No need to switch context



Electric Cloud can drop you two bands

Conclusion

- **No need to tolerate slow builds anymore**
- **Faster builds mean**
  - Faster time to market
  - Higher quality
  - Ability to do more with less

More Information

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- **For more information or to answer additional questions:**
  - Visit our website: www.electric-cloud.com
  - E-mail: info@electric-cloud.com
  - Phone: 650-962-4777

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