Ext4: The Next Generation of Ext2/3

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Agenda

- New features in ext3 you might not know about
- What's cool about ext3
- What's not
- Why fork ext3->ext4?
- New ext4 features on deck
- How to get involved

New features in ext3 (you might not know about)

- Directory indexing (hash tree directories)
  - To enable:
    - tune2fs -O dir_index /dev/XX
    - e2fsck -fD /dev/XX
  - Can make some workloads slower
- Online resizing
  - Need to create filesystem with -O resize_inode
  - Requires e2fsprogs 1.36 or greater, default in e2fsprogs 1.39
- Various performance enhacements

What's cool about ext3

- Very large user community
- Very large developer community
  - From a large number of companies:
    - Red Hat, IBM, Bull, Clusterfs, Google, NEC, others
- Emphasis on robustness above all else
  - Simple filesystem format
  - “PC Class hardware sucks”

What's not so cool about ext3?

- 16TB filesystem size limitation (32-bit block numbers)
- Second resolutiom timestamps
- 32,768 limit on subdirectories
- Performance limitations

Why Ext4?

- No development 2.7 tree
  - ... and changes take longer than the 2-3 months between 2.6 releases
- Large userspace community
  - People like davem, rusty, akpm, torvalds get cranky if their source trees get trashed
- Many changes on-deck require format changes
- Allows more experimentation than if the work is done outside of mainline
  - Make sure users understand that ext4 is risky: mount -t ext4dev
- Downsides
  - bug fixes must be applied to two code bases
  - smaller testing community

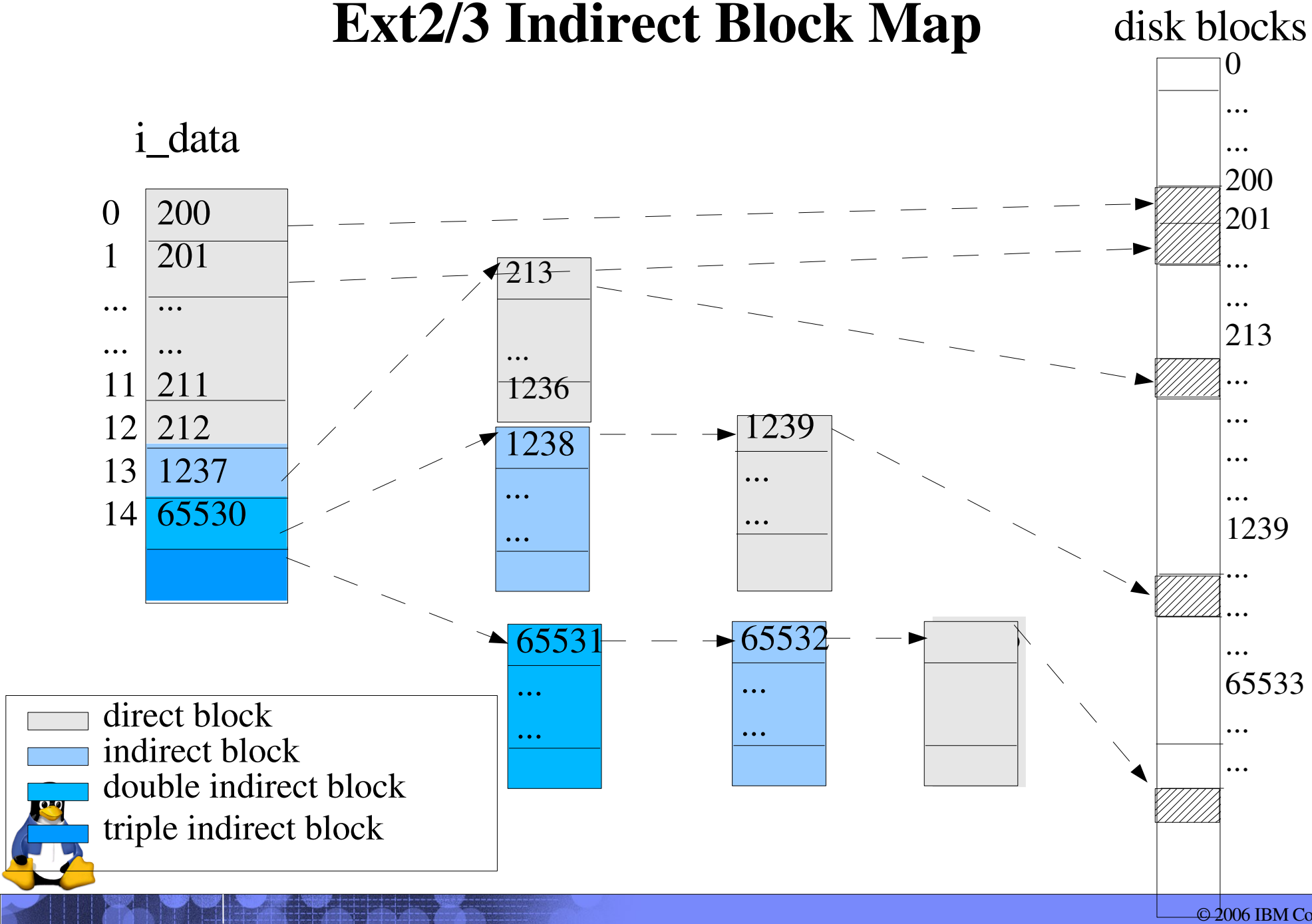
Features (under development)

- Abillity to use > 16TB filesystems (going beyond 32-bit block numbers)
- Replacing indirect blocks with extents
- More efficient block allocation
- Allow greater than 32k subdirectories
- Nanosecond timestamps
- Metadata checksumming
- Uninitialized groups to speed up mkfs/fsck
- Persistent file allocation
- Online defragmentation

Extents

- Indirect block maps are incredibly inefficient
  - One extra block read (and seek) every 1024 blocks
- Really obvious when deleting big CD/DVD image files

Ext2/3 Indirect Block Map

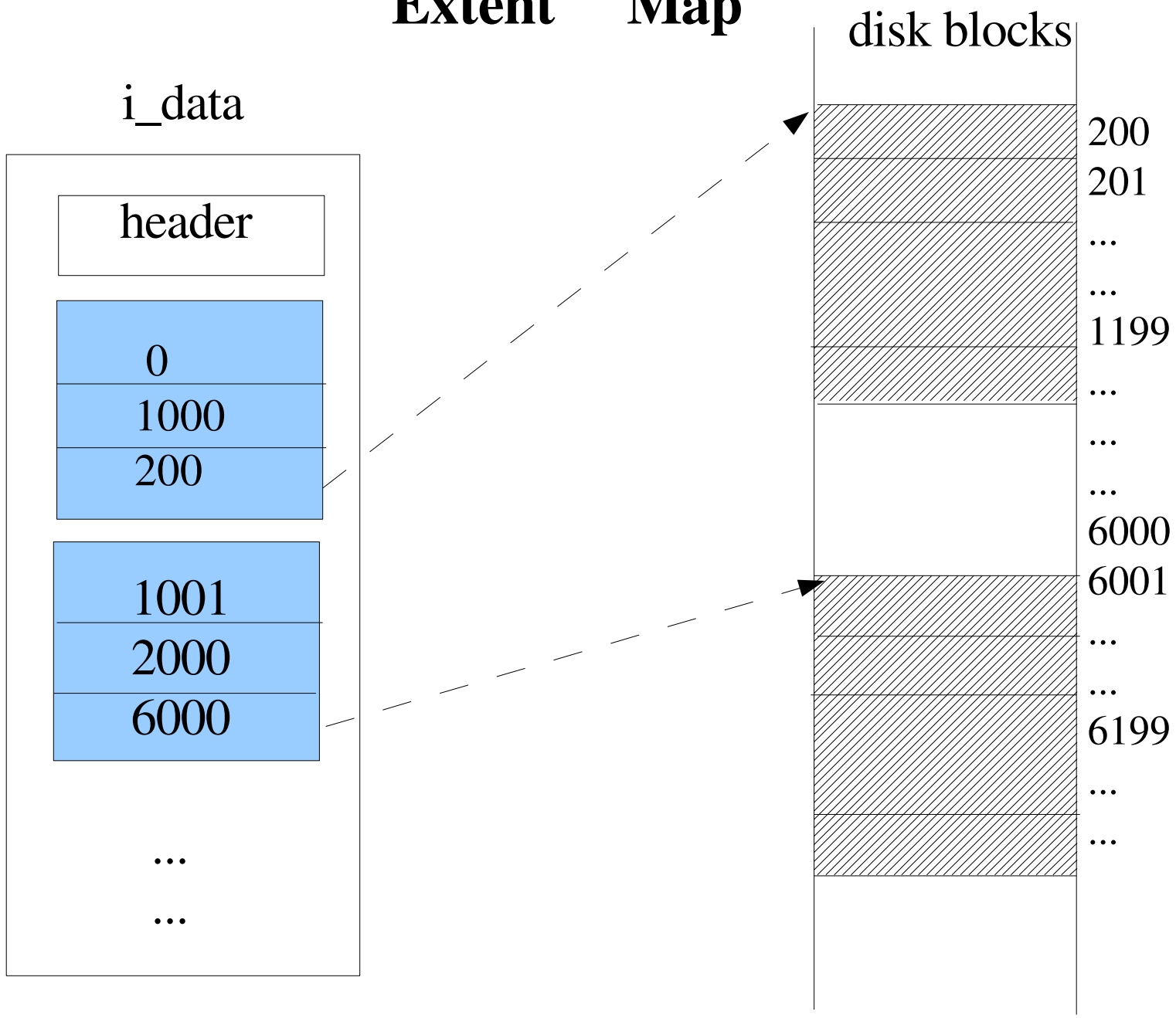


Extents

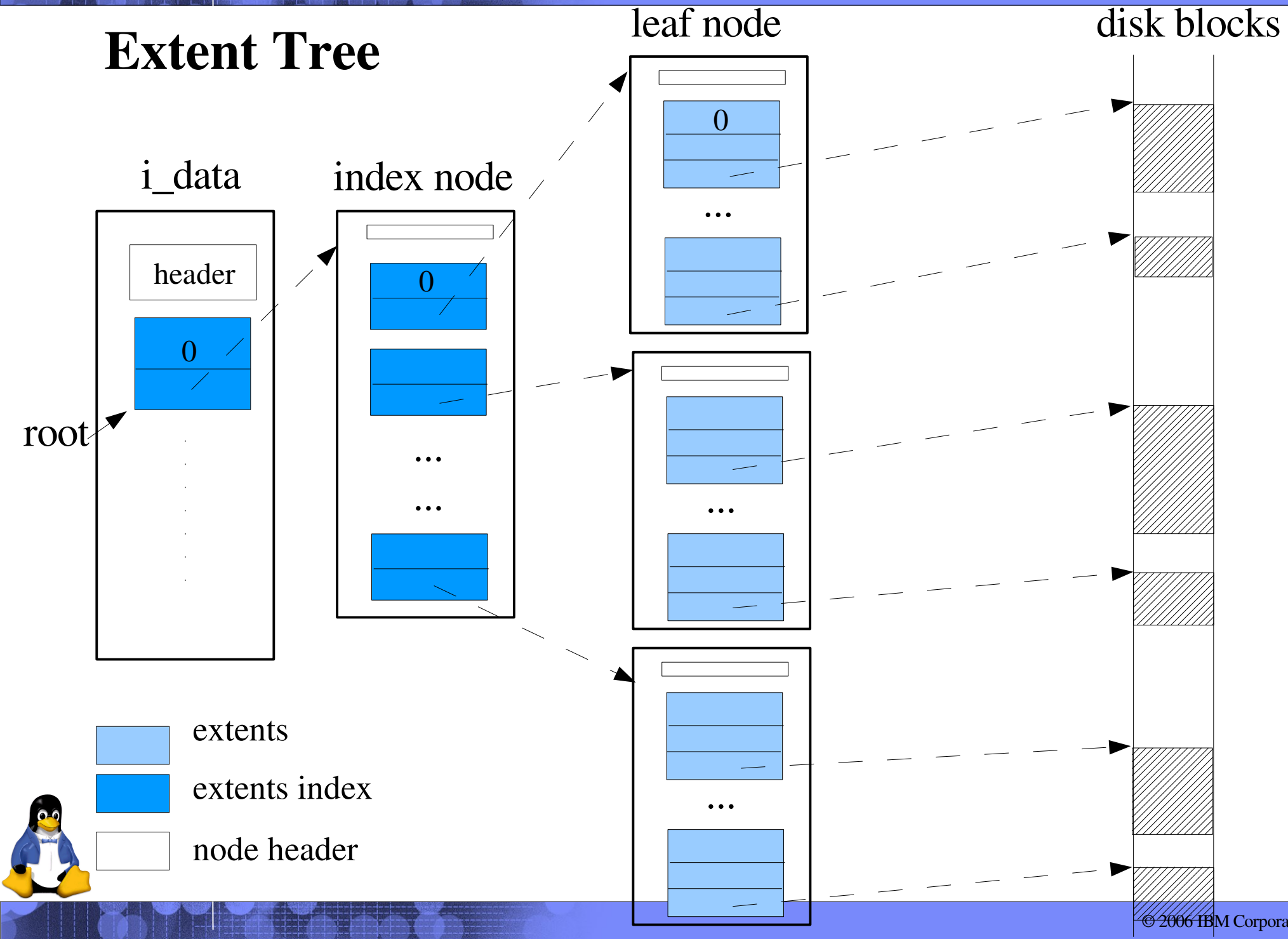
- Extents is an efficient way to represent large file
- An extent is a single descriptor for a range of contiguous blocks

logical	length	physical
0	1000	200

Extent Map



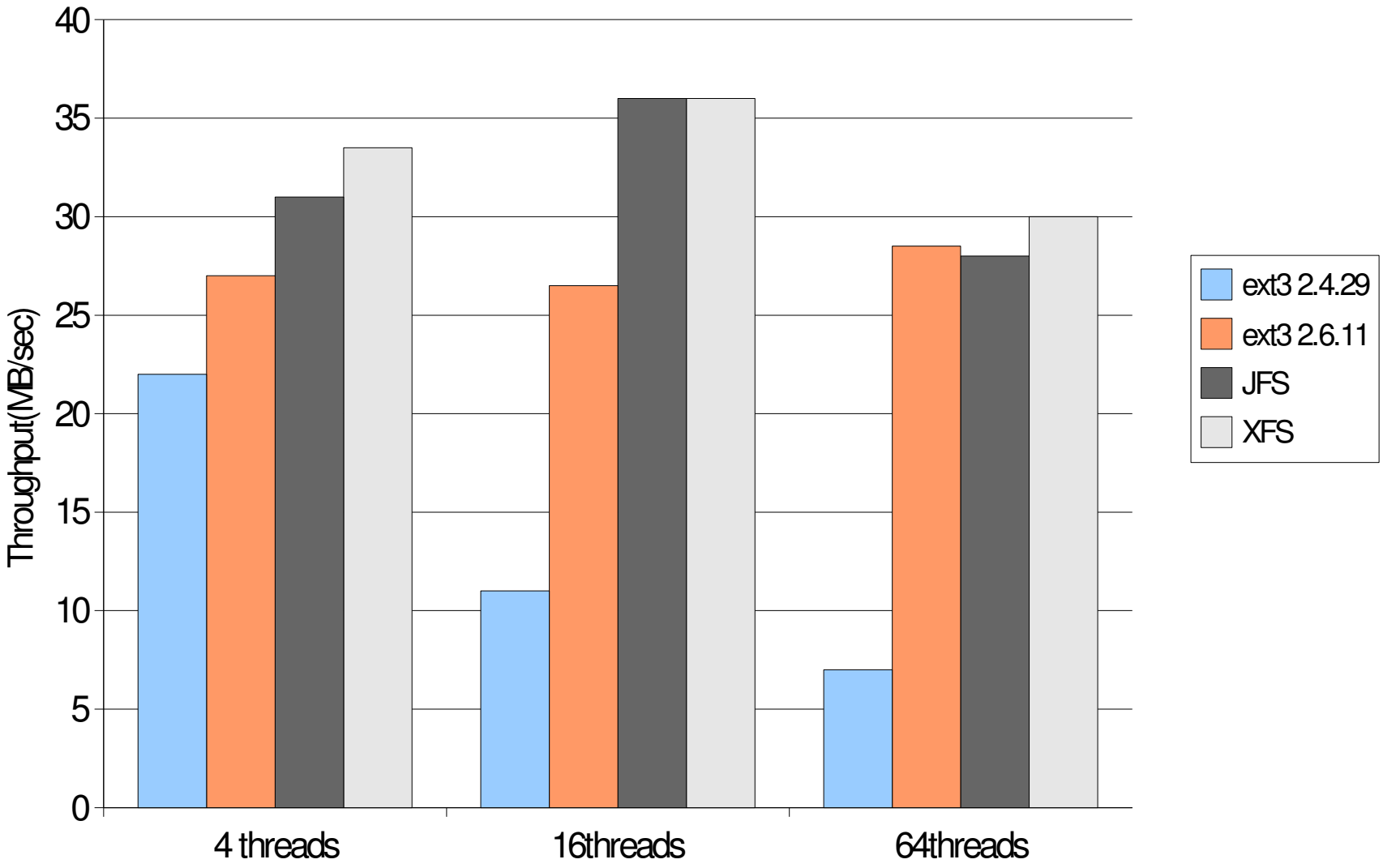
Extent Tree



Extent Related Works

- Multiple block allocation
  - Allocate contiguous blocks together
    - Reduce fragmentation, reduce extent meta-data
    - Stripe aligned allocations
- Delayed allocation
  - Defer block allocation to writeback time
  - Improve chances allocating contiguous blocks, reducing fragmentation
  - Trickier to implement in ordered mode

tiobench sequential write



64-bit block numbers

- Most of the hard work done as part of the extents changes
  - Original lustre patches provide 48-bit block numbers. Enough for a 2**60 filesystems
- Other changes
  - Superblock fields
  - Block group descriptors (required doubling their size)
  - Journal inode (new jbd2 layer)

Expanded inode

- Inode size is normally 128 bytes in ext3
- But can be 256, 512, 1024, etc. up to filesystem blocksize
- Extra space used for fast extended attributes
- 256 bytes needed for ext4 features
  - Nanosecond timestamps
  - Inode change version # for Lustre, nfsv4

Persistent file allocation

- Allow applications to preallocate blocks for a file without having to initialize them
  - Contiguous allocation to reduce fragmentation
    - Irrespective of order that blocks are written
    - While avoidng overhead of zeroing blocks
  - Guaranteed space allocation
  - Useful for Streaming audio/video, databases
- Implemented as unitialized extents
  - MSB of ee_len used to flag “invalid” extents
  - Reads return zero
  - Writes split the extent into valid and invalid extents

Metadata checksuming

- Proof of concept implementation described in the Iron Filesystem paper (from University of Wisconsin)
- Storage trends: reliability and seek times not keeping up with capacity increases
- Add checksums to extents, superblock, block group descriptors, inodes, journal

Getting involved

- Mailing list: linux-ext4@vger.kernel.org
- Wiki: http://ext4.wiki.kernel.org
  - Still needs work; anyone want to jump in and help, talk to us
- Weekly conference call; minutes on the wiki
  - Contact us if you'd like dial in
- IRC channel: irc.oftc.net, /join #linuxfs

The Ext4 Development Team

- Alex Thomas
- Andreas Dilger
- Theodore Tso
- Stephen Tweedie
- Mingming Cao
- Dave Kleikamp
- Badari Pulavarathy
- Avantikia Mathur
- Andrew Morton
- Laurent Vivier
- Alexandre Ratchov
- Eric Sandeen
- Takashi Sato
-

Conclusion

- Ext4 work just beginning
- Extents merged, other patches on deck
- Should be a lot of fun!
- Watch this space....