



INNODB[®]

Transactional Storage for MySQL
FAST. RELIABLE. PROVEN.

InnoDB Internals: InnoDB File Formats and Source Code Structure

MySQL University, October 2009

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Today's Topics

- Goals of InnoDB
- Key Functional Characteristics
- InnoDB Design Considerations
- InnoDB Architecture
- InnoDB On Disk Format
- Source Code Structure
- Q & A

Goals of InnoDB



- OLTP oriented
- Performance, Reliability, Scalability
- Data Protection
- Portability



InnoDB Key Functional Characteristics

- Full transaction support
- Row-level locking
- MVCC
- Crash recovery
- Efficient IO

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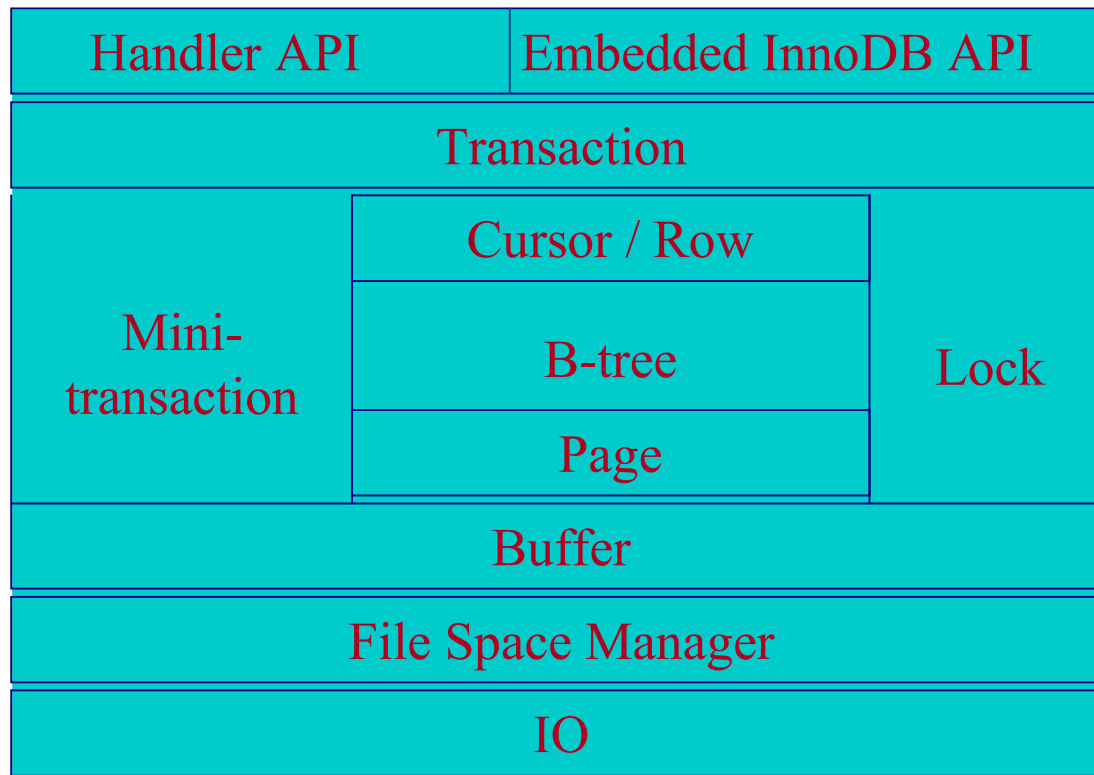
Design Considerations

- Modeled on Gray & Reuter's "*Transactions Processing: Concepts & Techniques*"
- Also emulated the Oracle architecture
- Added unique subsystems
 - Doublewrite
 - Insert buffering
 - Adaptive hash index
- Designed to evolve with changing hardware & requirements

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InnoDB Architecture

Server  Applications 



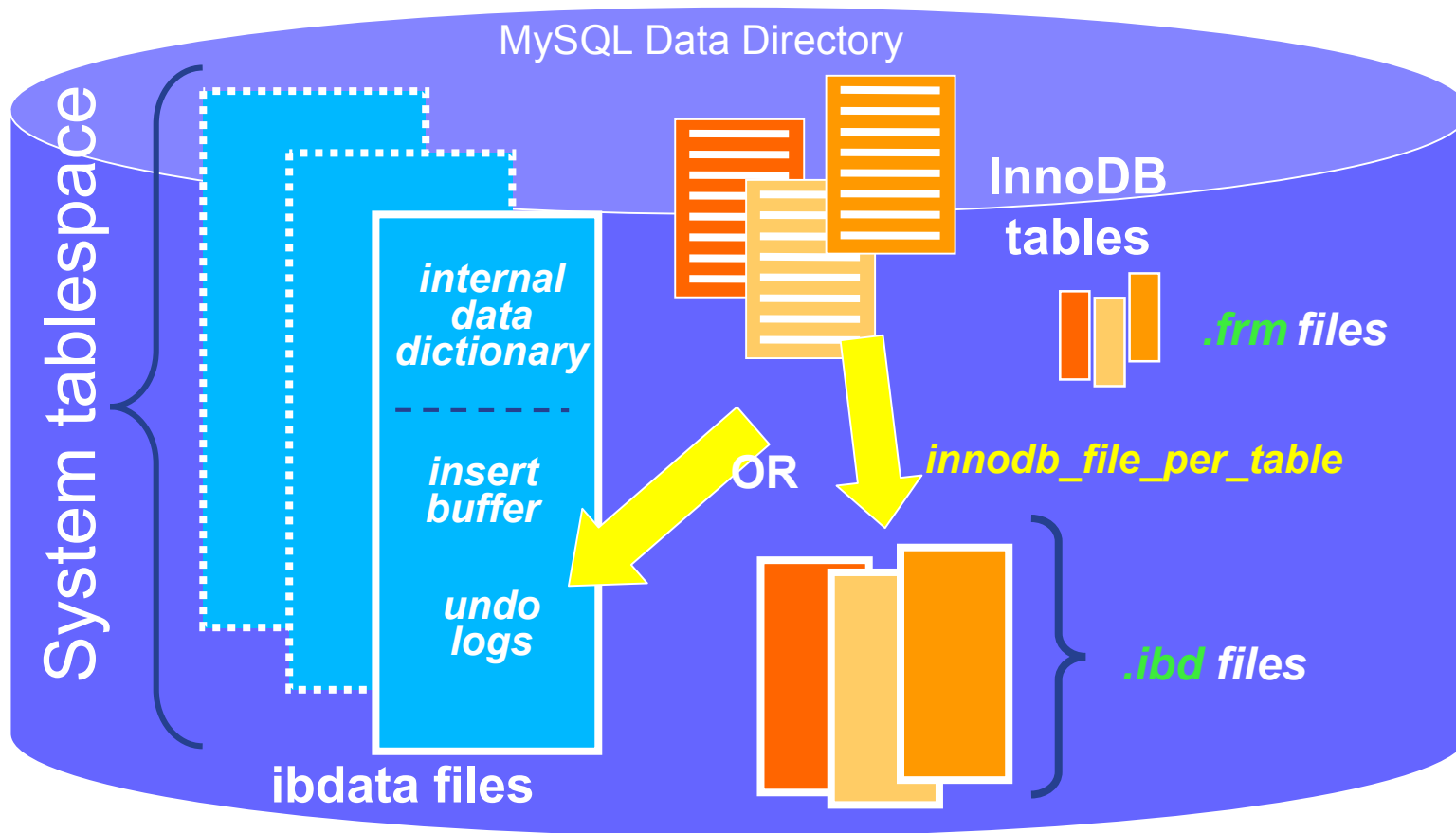
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InnoDB On Disk Format

- InnoDB Database Files
- InnoDB Tablespaces
- InnoDB Pages / Extents
- InnoDB Rows
- InnoDB Indexes
- InnoDB Logs
- File Format Design Considerations

InnoDB Database Files





InnoDB Tablespace

- A tablespace consists of multiple files and/or raw disk partitions.
file_name:file_size[:autoextend[:max:max_file_size]]
- A file/partition is a collection of segments.
- A segment consists of fixed-length pages.
- The page size is always 16KB in uncompressed tablespaces, and 1KB-16KB in compressed tablespaces (for both data and index).

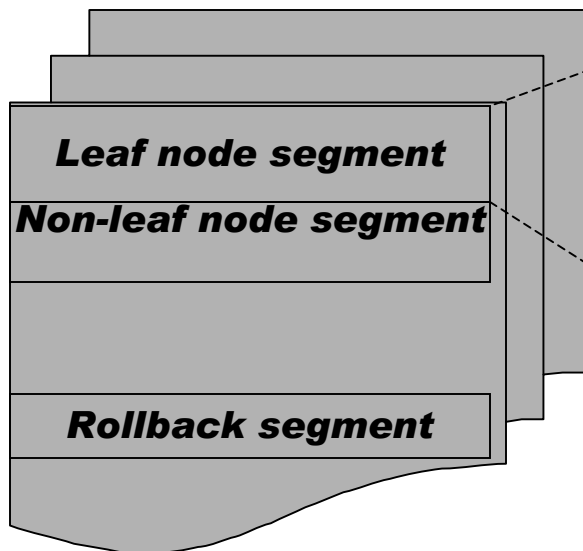


System Tablespace

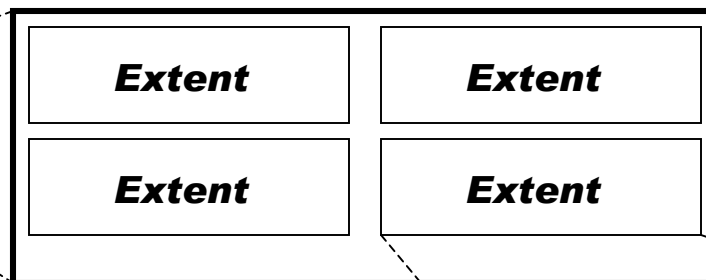
- Internal Data Dictionary
- Undo
- Insert Buffer
- Doublewrite Buffer
- MySQL Replication Info

InnoDB Tablespaces

Tablespace

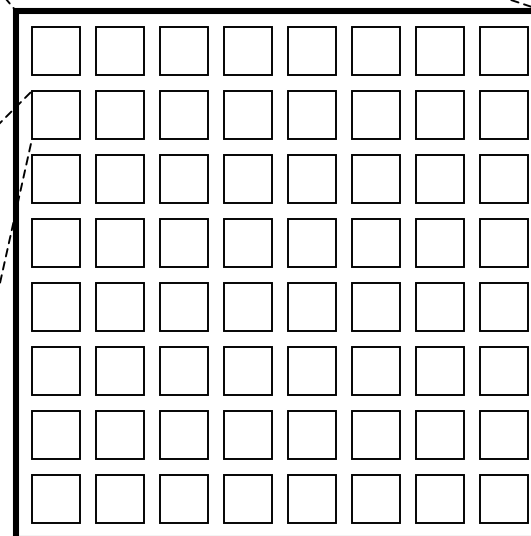


Segment

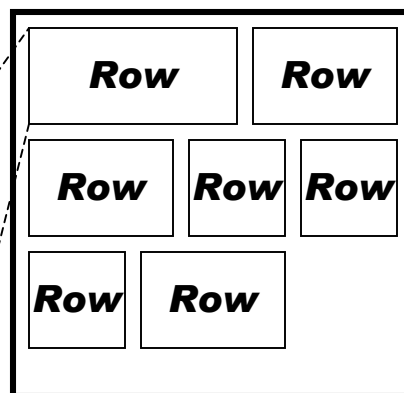
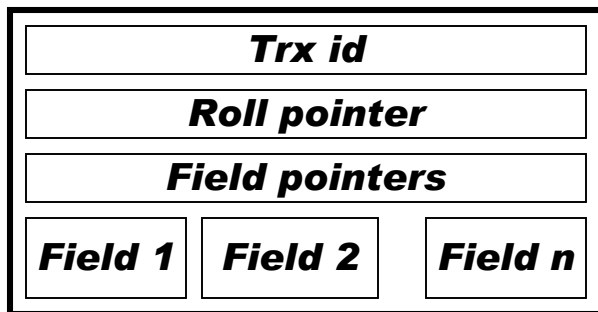


Extent

Page



Row



an extent = 64 pages

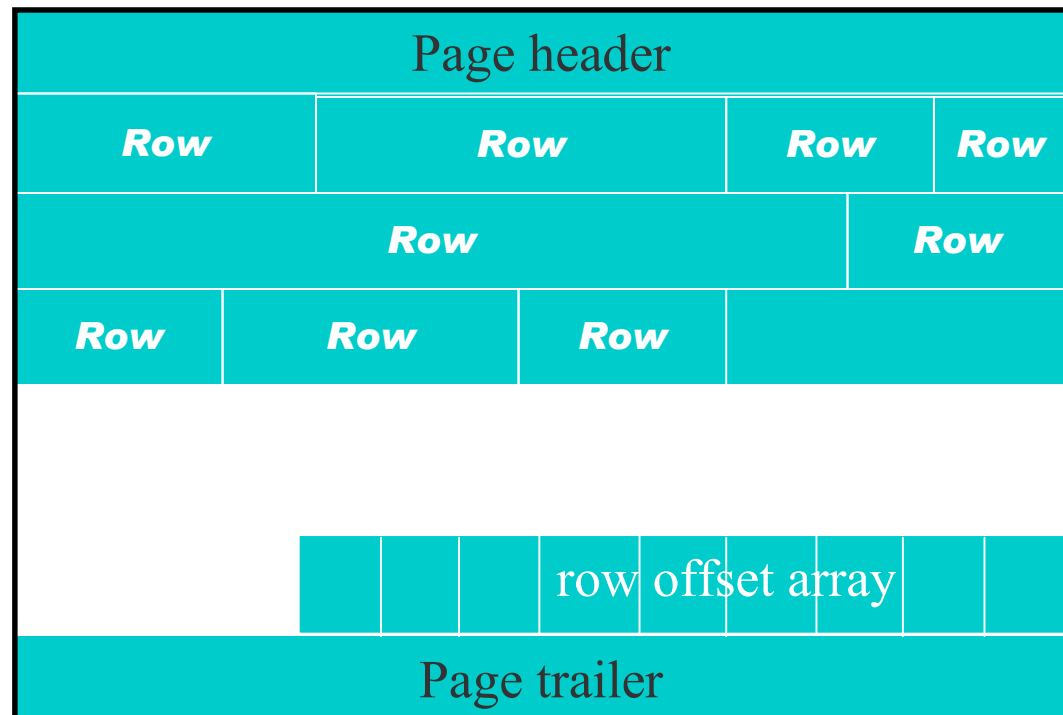
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InnoDB Pages

InnoDB Page Types		
Symbol	Value	Notes
FIL_PAGE_INODE	3	File segment inode
FIL_PAGE_INDEX	17855	B-tree node
FIL_PAGE_TYPE_BLOB	10	Uncompressed BLOB page
FIL_PAGE_TYPE_ZBLOB	11	1 st compressed BLOB page
FIL_PAGE_TYPE_ZBLOB2	12	Subsequent compressed BLOB page
FIL_PAGE_TYPE_SYS	6	System page
FIL_PAGE_TYPE_TRX_SYS	7	Transaction system page
others		i-buf bitmap, l-buf free list, file space header, extent desp page, new allocated page

InnoDB Pages

A page consists of: a page header, a page trailer, and a page body (rows or other contents).

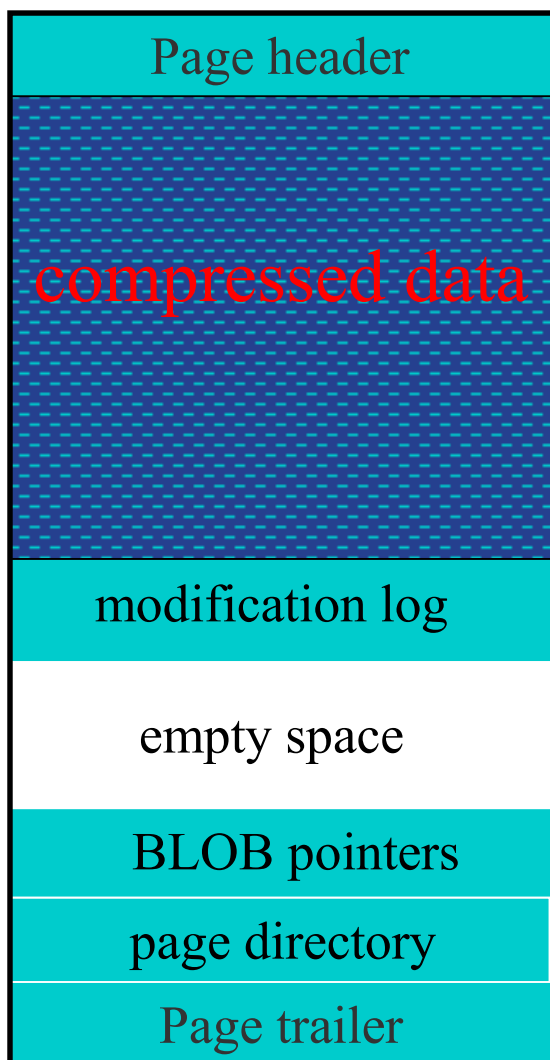


Page Declares

```
typedef struct                                /* a space address */
{
    ulint      pageno;                        /* page number within the file */
    ulint      boffset;                       /* byte offset within the page */
} fil_addr_t;

typedef struct
{
    ulint      checksum;                      /* checksum of the page (since 4.0.14) */
    ulint      page_offset;                   /* page offset inside space */
    fil_addr_t previous;                      /* offset or fil_addr_t */
    fil_addr_t next;                          /* offset or fil_addr_t */
    dulint     page_lsn;                      /* lsn of the end of the newest
                                           modification log record to the page */
    PAGE_TYPE  page_type;                     /* file page type */
    dulint     file_flush_lsn;                /* the file has been flushed to disk
                                           at least up to this lsn */
    int        space_id;                      /* space id of the page */
    char       data[];                        /* will grow */
    ulint      page_lsn;                      /* the last 4 bytes of page_lsn */
    ulint      checksum;                      /* page checksum, or checksum magic, or 0 */
} PAGE, *PAGE;
```

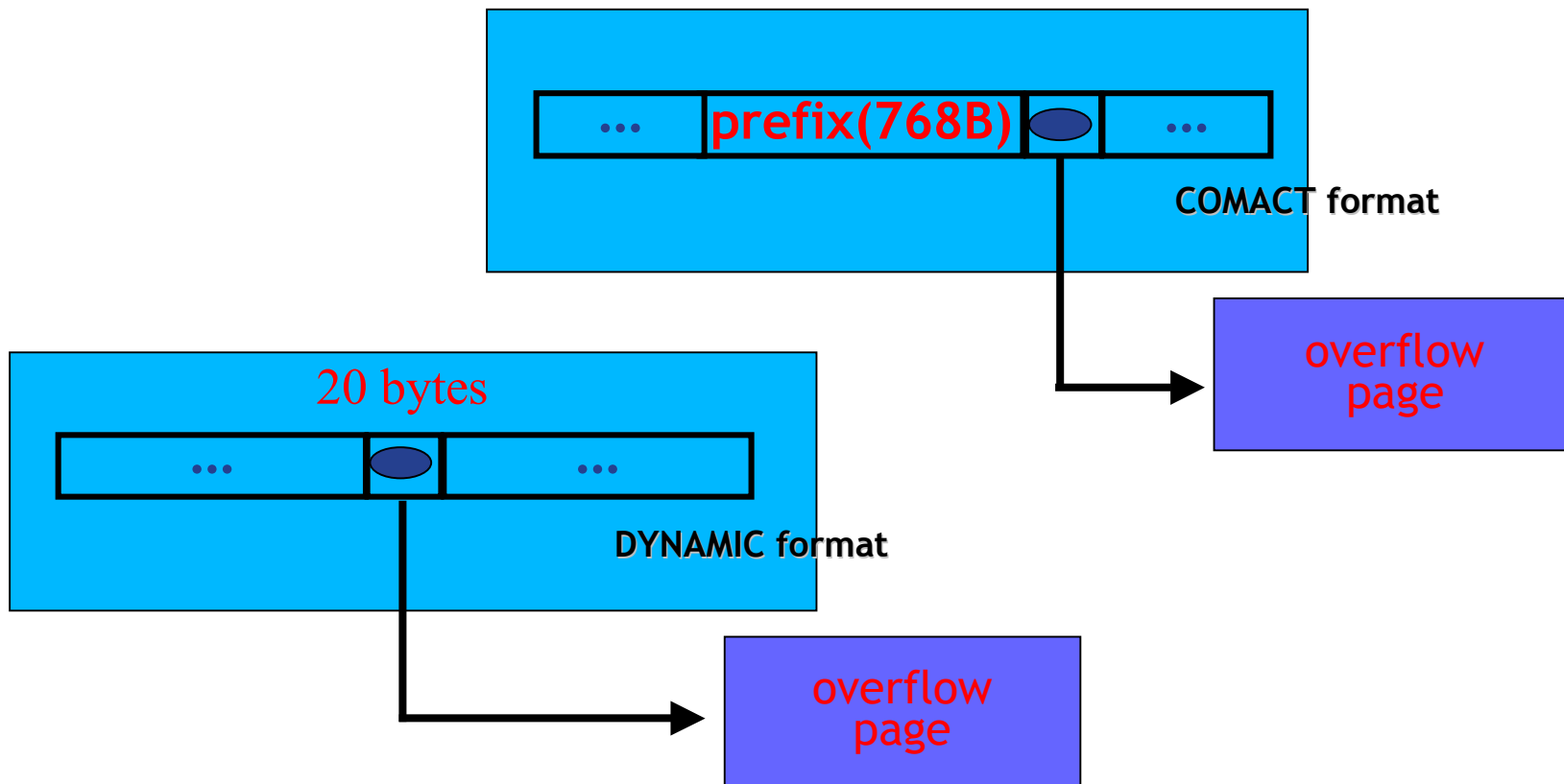
InnoDB Compressed Pages



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- InnoDB keeps a “modification log” in each page
- Updates & inserts of small records are written to the log w/o page reconstruction; deletes don’t even require uncompression
- Log also tells InnoDB if the page will compress to fit page size
- When log space runs out, InnoDB uncompresses the page, applies the changes and recompresses the page

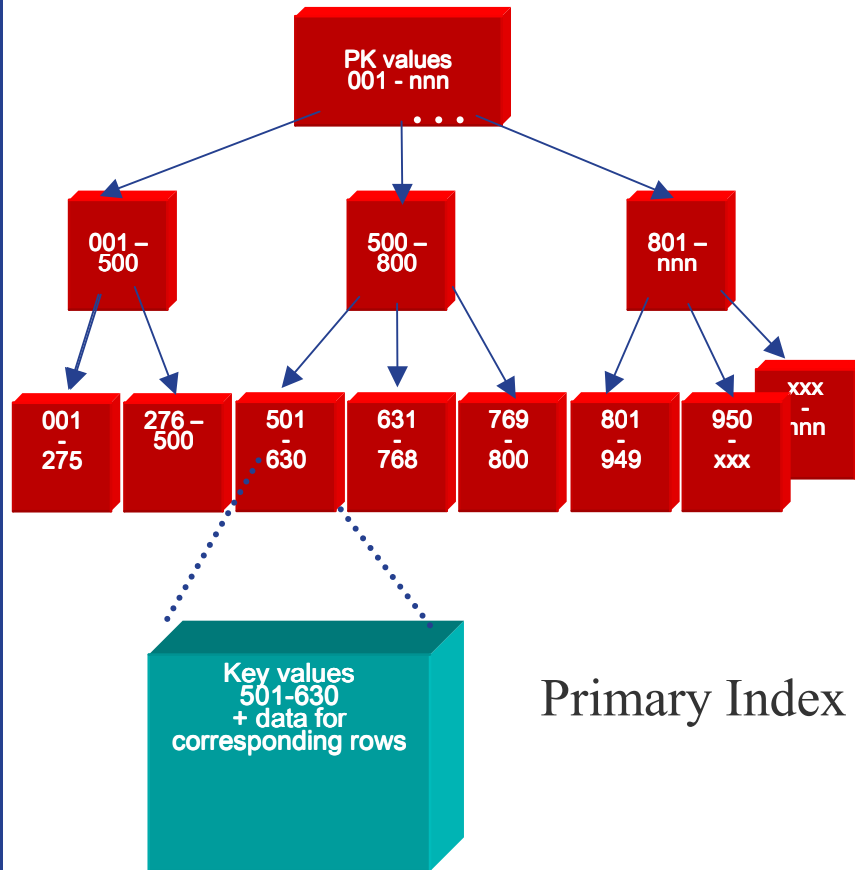
InnoDB Rows



Record hdr | *Trx ID* | *Roll ptr* | *Fld ptrs* | *overflow-page ptr* .. *Field values*

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InnoDB Indexes - Primary



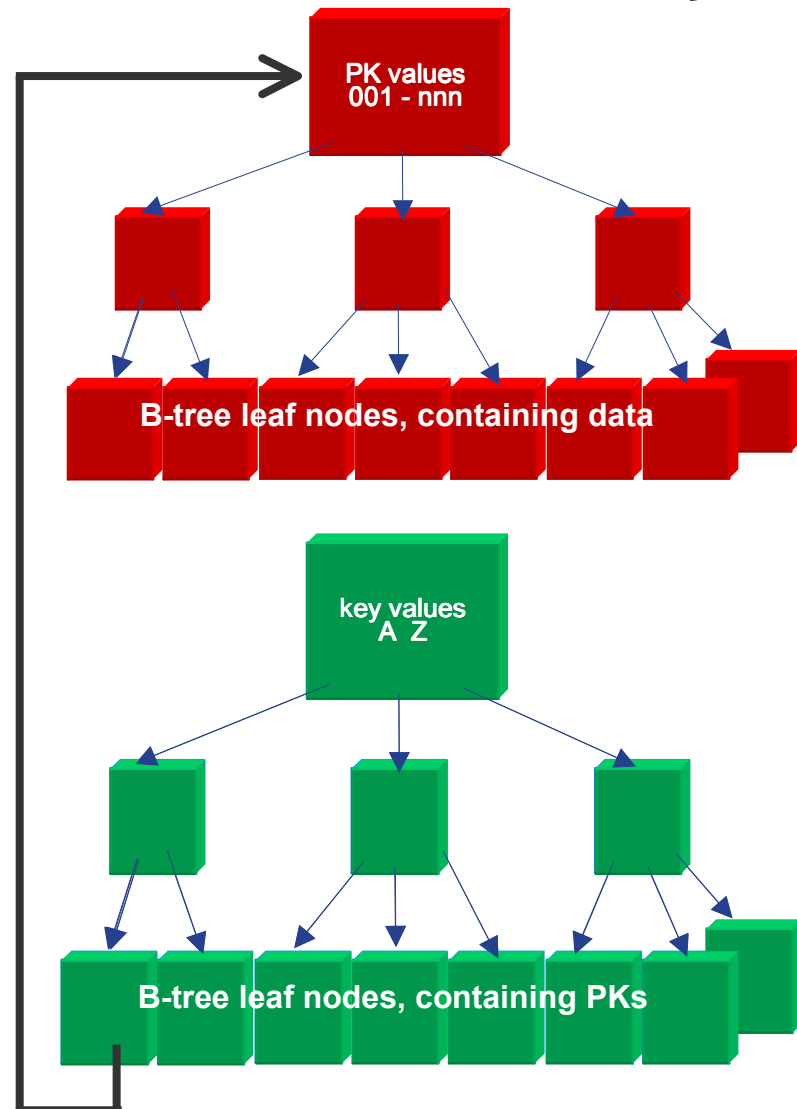
- Data rows are stored in the B-tree leaf nodes of a clustered index
- B-tree is organized by primary key or non-null unique key of table, if defined; else, an internal column with 6-byte ROW_ID is added.

InnoDB Indexes - Secondary

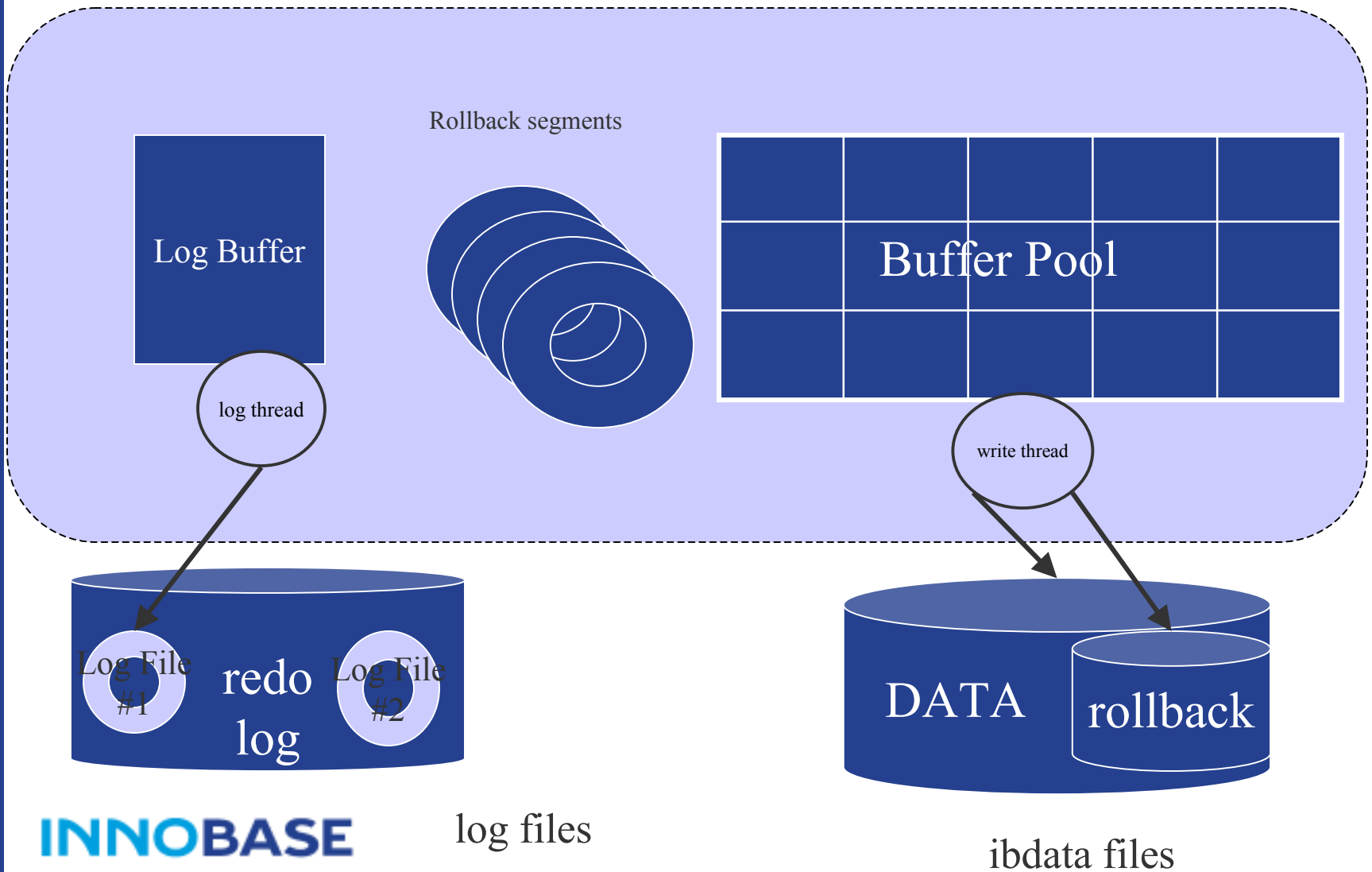
- Secondary index B-tree leaf nodes contain, for each key value, the primary keys of the corresponding rows, used to access clustering index to obtain the data

Secondary Index

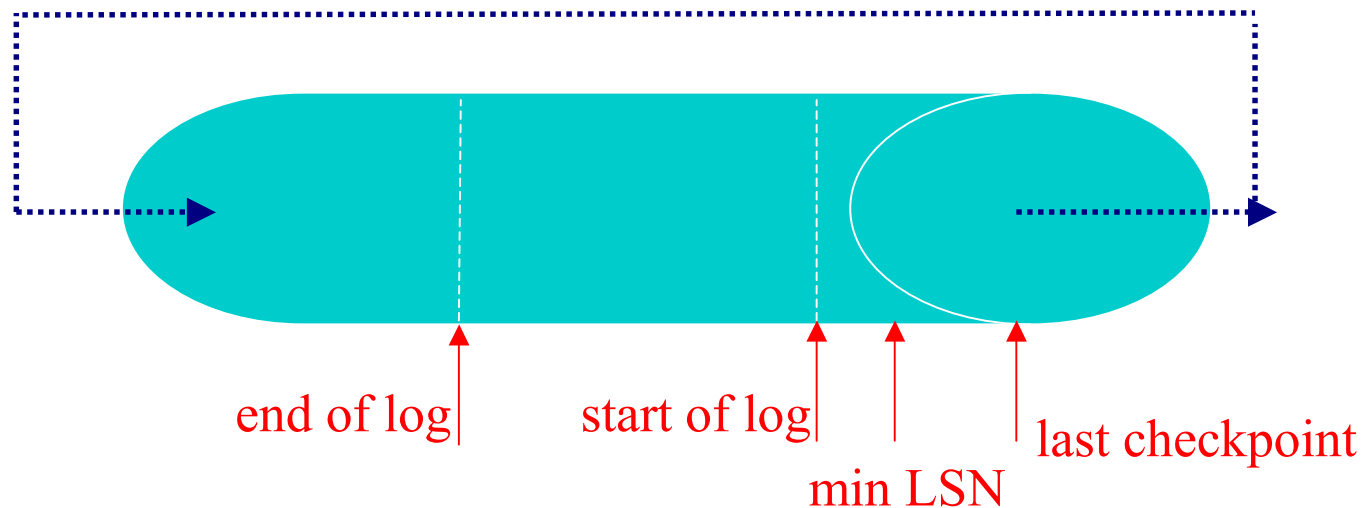
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InnoDB Logging



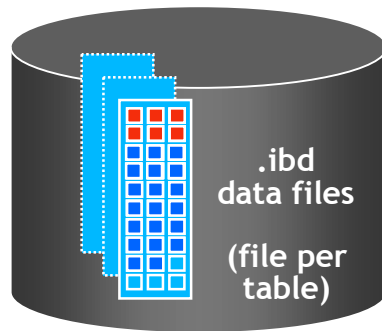
InnoDB Redo Log



Redo log structure:

<i>Space id</i>	<i>PageNo</i>	<i>OpCode</i>	<i>Data</i>
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File Format Management



- Builtin InnoDB format: “Antelope”
- New “Barracuda” format enables compression, ROW_FORMAT=DYNAMIC
 - Fast index creation, other features do not require Barracuda file format
- Builtin InnoDB can access “Antelope” databases, but not “Barracuda” databases
 - Check file format tag in system tablespace on startup
- Enable a file format with new dynamic parameter `innodb_file_format`
- Preserves ability to downgrade easily



InnoDB File Format Design Considerations

- Durability
 - Logging, doublewrite, checksum;
- Performance
 - Insert buffering, table compression
- Efficiency
 - Dynamic row format, table compression
- Compatibility
 - File format management



Source Code Structure

- 31 subdirectories
- Relevant InnoDB source files on file formats
 - Tablespace: fsp0fsp {.c, .ic, .h}
 - Page: page0page, page0zip {.c, .ic, .h}
 - Log: log0log {.c, .ic, .h}



Source Code Subdirectories

- buf
- data
- db
- dict
- dyn
- eval
- fil
- fsp
- fut
- ha
- handler
- ibuf
- include
- lock
- log
- math
- mem
- mtr
- os
- page
- pars
- que
- read
- rem
- row
- srv
- sync
- thr
- trx
- usr
- ut



Summary:

Durability, Performance, Compatibility & Efficiency

- InnoDB is the leading transactional storage engine for MySQL
- InnoDB's architecture is well-suited to modern, on-line transactional applications; as well as embedded applications.
- InnoDB's file format is designed for high durability, better performance, and easy to manage

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Q&A

QUESTIONS
ANSWERS

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InnoDB Size Limits

- Max # of tables: **4 G**
- Max size of a table: **32TB**
- Columns per table: **1000**
- Max row size: **n*4 GB**
 - 8 kB if stored on the same page
 - n*4 GB with n BLOBs
- Max key length: **3500**
- Maximum tablespace size: **64 TB**
- Max # of concurrent trxs: **1023**