DataBlitz™

DataBlitz
Main Memory DataBase System

What is DataBlitz ?

DataBlitz™

- **DataBlitz is a general purpose Main Memory DataBase System that enables:**
  - high-speed access to data
  - concurrent access to shared data
  - data integrity to be preserved in the presence of faults or failures
- **DataBlitz differs from typical commercial database systems in that:**
  - data is stored in main memory, not on disk
  - data is accessed directly, not over a network
  - there is no buffer manager
  - lower level APIs are exposed to applications

DataBlitz's Broad Applicability

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- DataBlitz's high performance {high throughput and short, predictable response times} makes it an ideal basis for a variety of purposes.
- The fast-emerging world of e-commerce thrives on speed and is a natural for DataBlitz.
- DataBlitz plays an enabling role in web servers as well as in web infrastructure (cache servers and other web accelerators).
- In financial trading, time is money. Even being a minute late may cause a trader to miss a market move. DataBlitz's performance and strength in transaction processing make it an ideal basis for on-line stock exchanges as well as for program traders.
- Decision-support systems, currently based on off-line analysis of information in data warehouses, can be made much more effective by means of rapid analysis of real-time data based on DataBlitz.

Target Telecom Applications

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- **Real-time billing:**
  - Bill for up-to-the-moment service and usage
  - Maintain billing history information
  - Keep customer and service summaries
- **Intelligent network applications**
  - 800 number translation
  - Intelligent 800 number service (via customer logic)
  - Call screening
  - Call routing (local number portability, unified messaging, etc.)
- **Switch-based functions**
  - Switching
  - Call routing
  - Call forwarding
  - Call waiting

High Performance Databases

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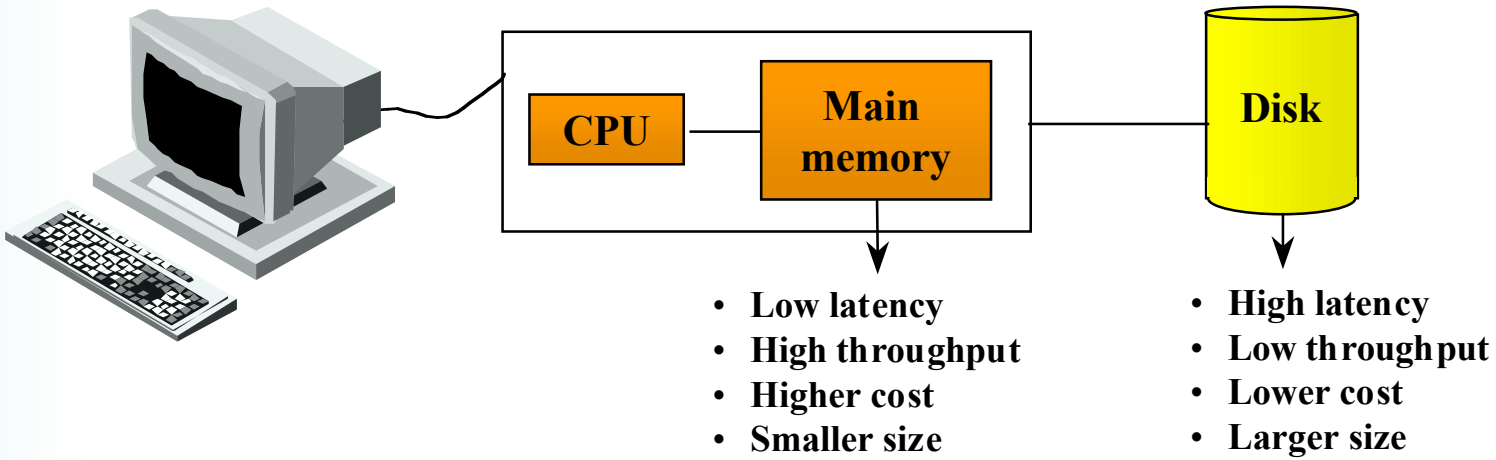
- **Characteristics**
  - High throughput with hundreds to thousands of transactions per second
  - Real-time response on the order of a few milliseconds
- **Data must be in main memory for performance attainment**
  - Disk accesses have high latency (~20 milliseconds) and low throughput
  - Main-memory accesses have low latency (~100 nanoseconds) and high throughtput and memory prices are falling reapidly



Existing Commercial Databases

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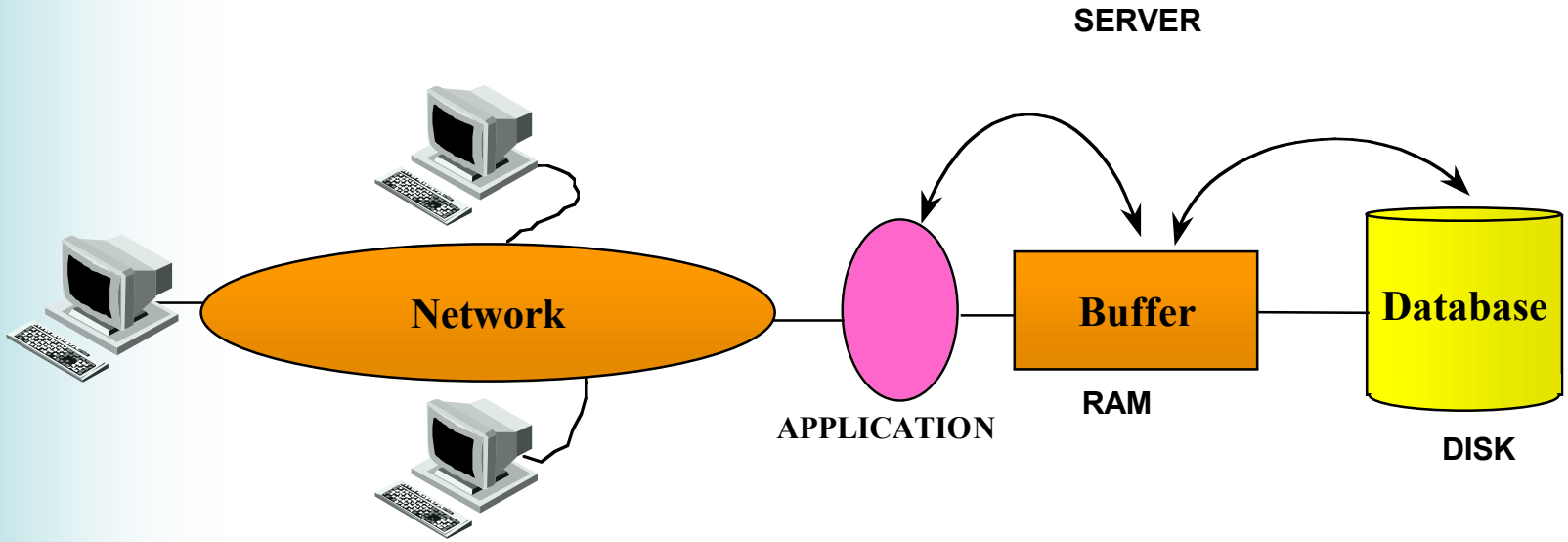
Most commercial systems assume data is primarily disk-resident



- Every access incurs
  - Network latency
  - Disk latency
  - Buffer manager overhead

DataBlitz -
High Performance MMDB System

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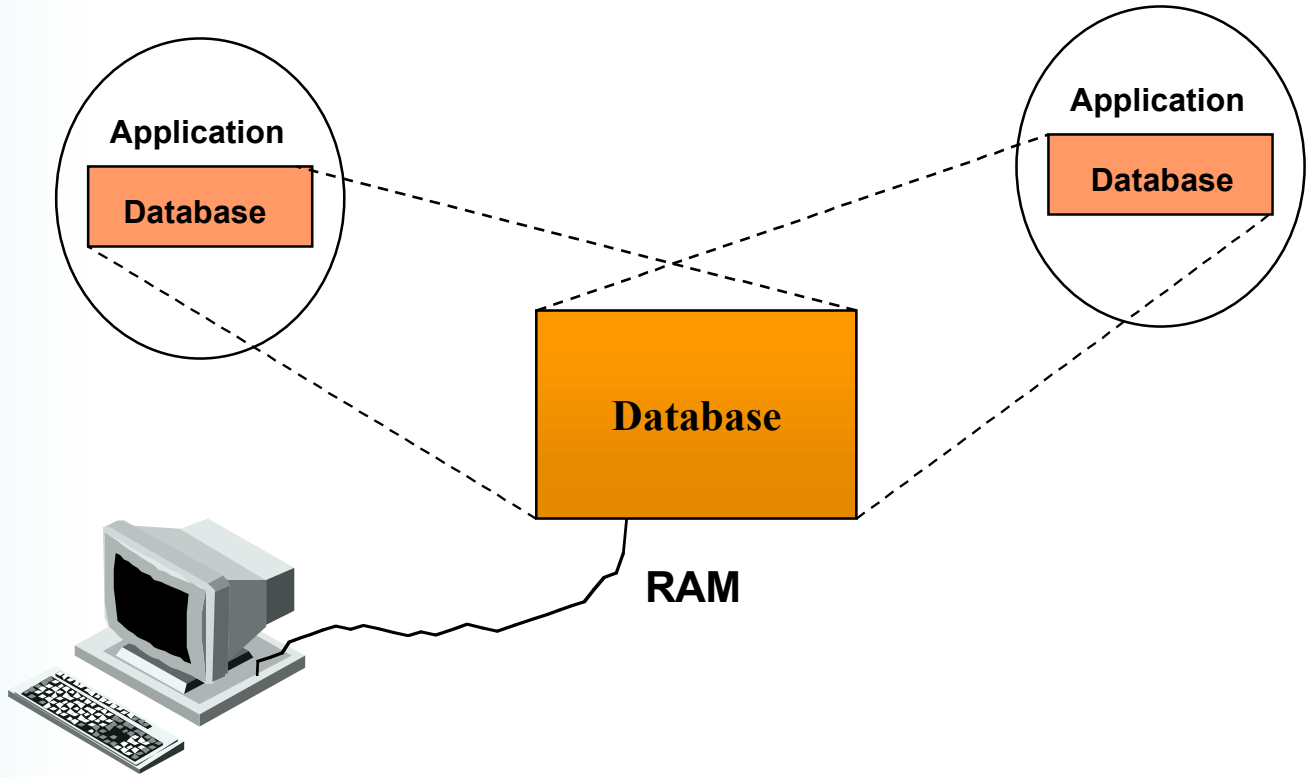
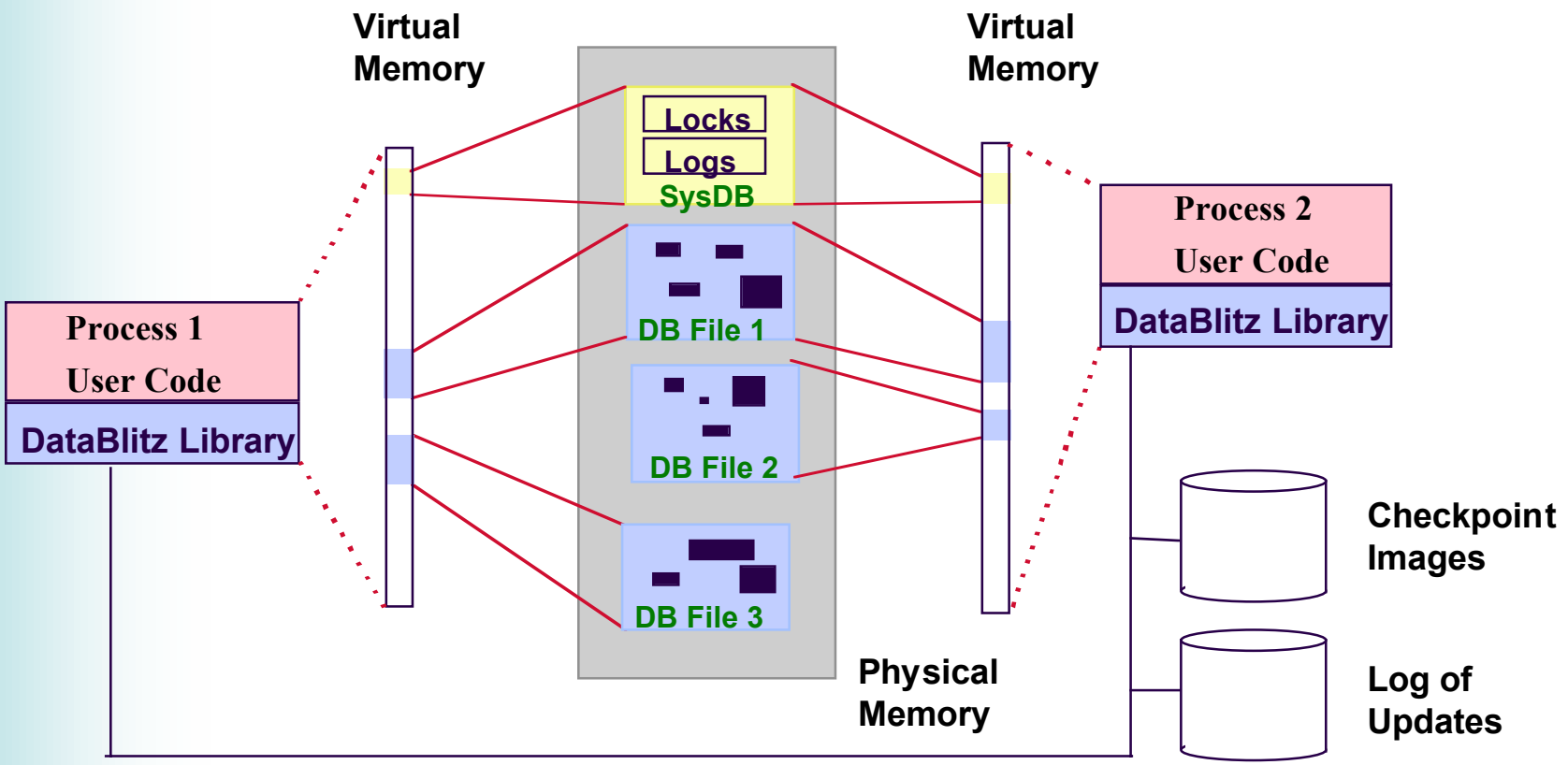
DataBlitz provides **real-time concurrent access to shared data**



True 64-bit Architecture support !

DataBlitz Architecture



Multiple Layers of Abstraction

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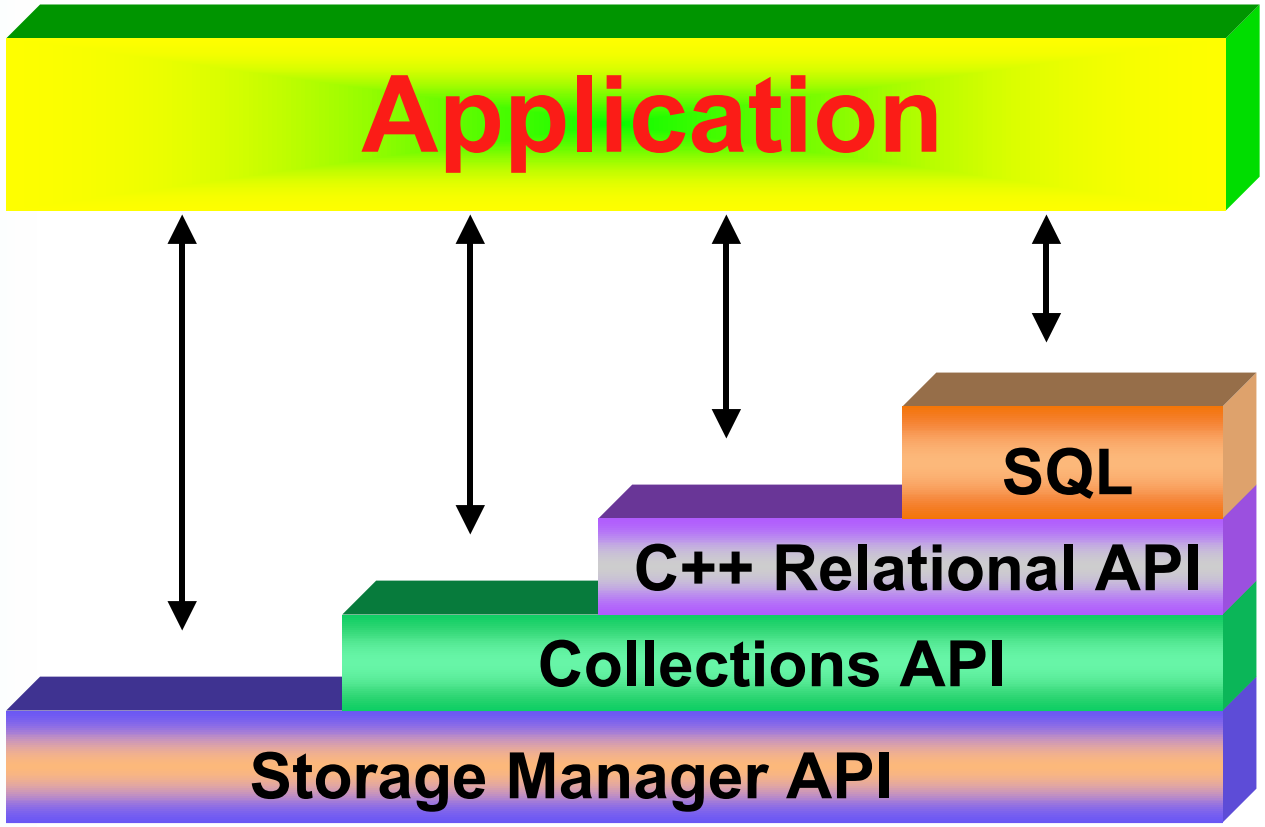
Applications can be written to use one of four APIs



Lower level APIs offer simpler functionality and even higher performance

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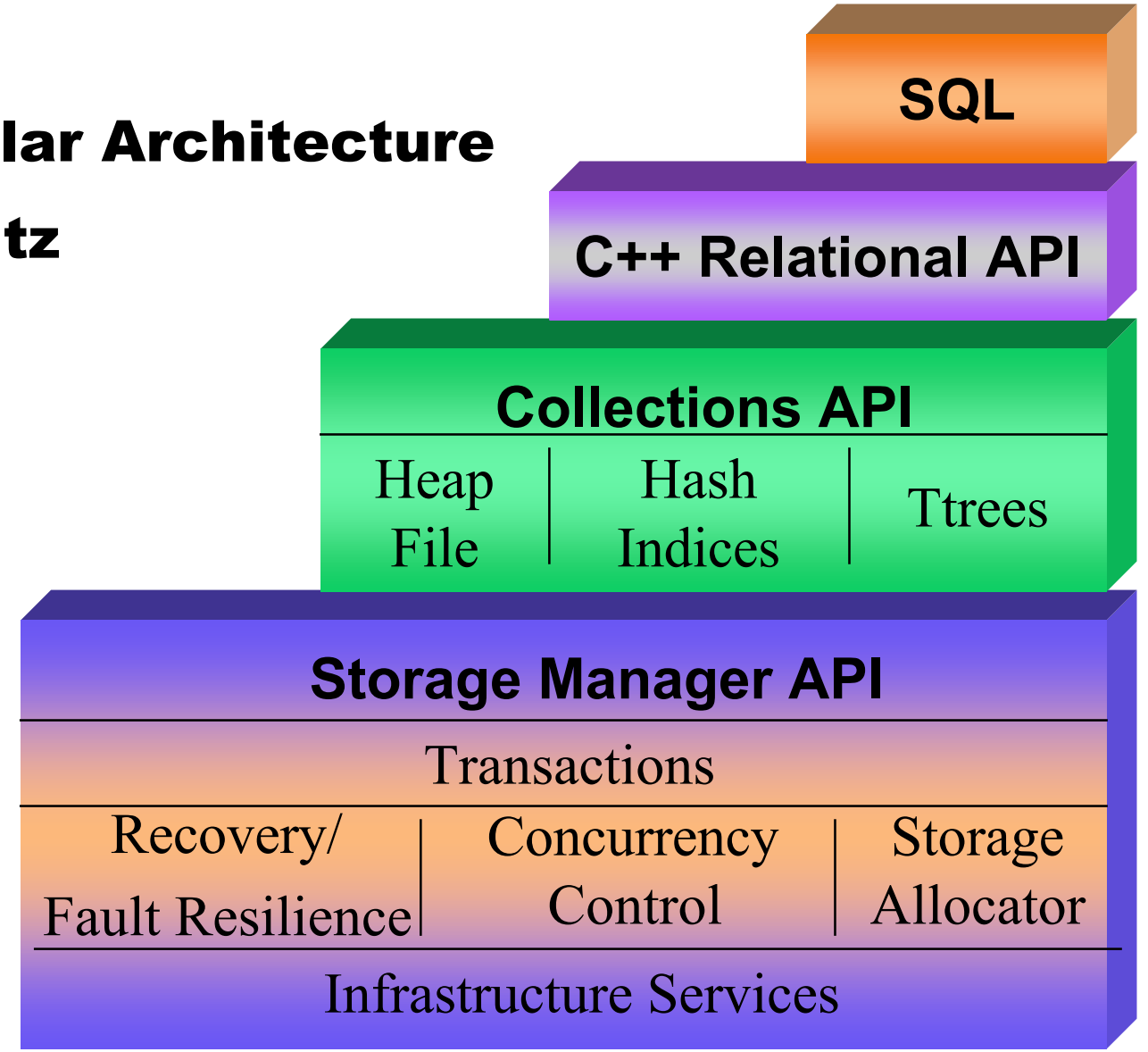
The Modular Architecture of DataBlitz



Infrastructure Services

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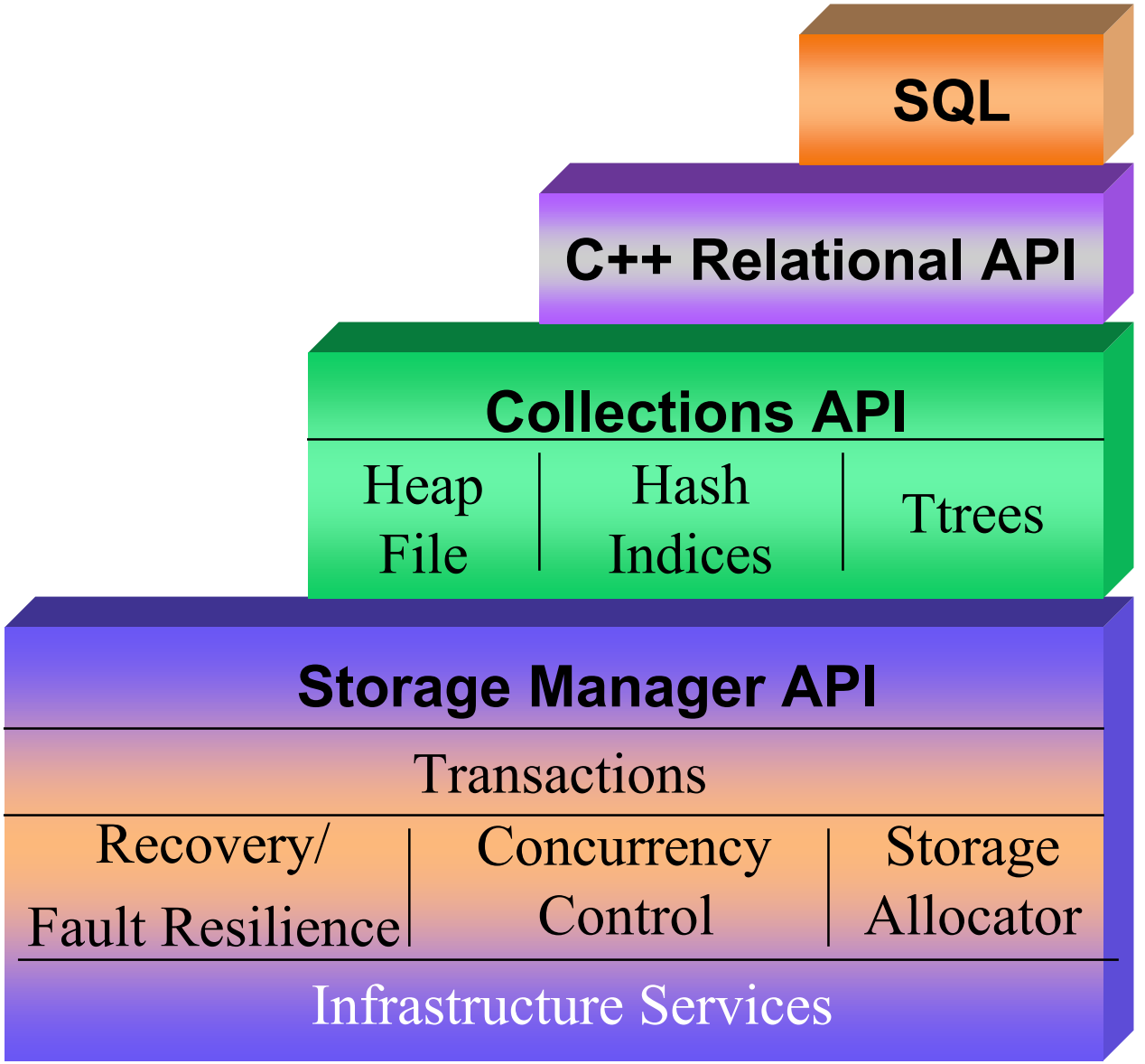

Infrastructure Services

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Database Management	Process Management	Communication Management

- Database management
  - Keeps track of database files in a DataBlitz system
  - Provides services to create, remove, resize, open, close and coordinate access to a database file
  - Manages the virtual address space of processes and keeps track of start addresses for mapped database files
  - Allocates/grows the underlying shared memory for a database file
- Process management
  - Keeps track of active processes and resources held by them (e.g. mutexes)
  - Performs cleanup for a failed process or thread
- Communication management
  - Provides a framework for messaging (local and remote)
  - Supports client/server remote procedure calls

Recovery/Fault Resilience

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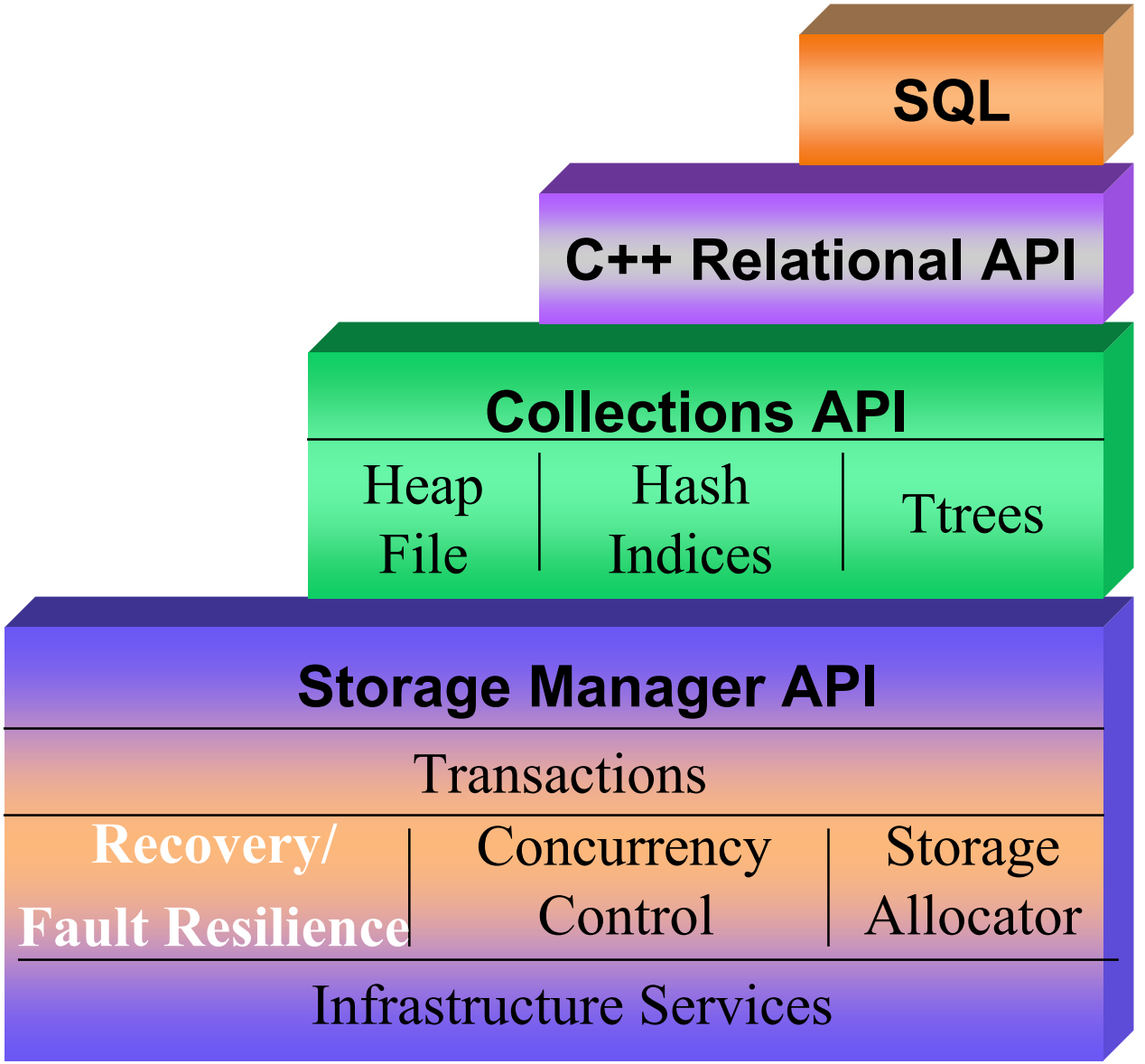

Recovery/Fault Resilience

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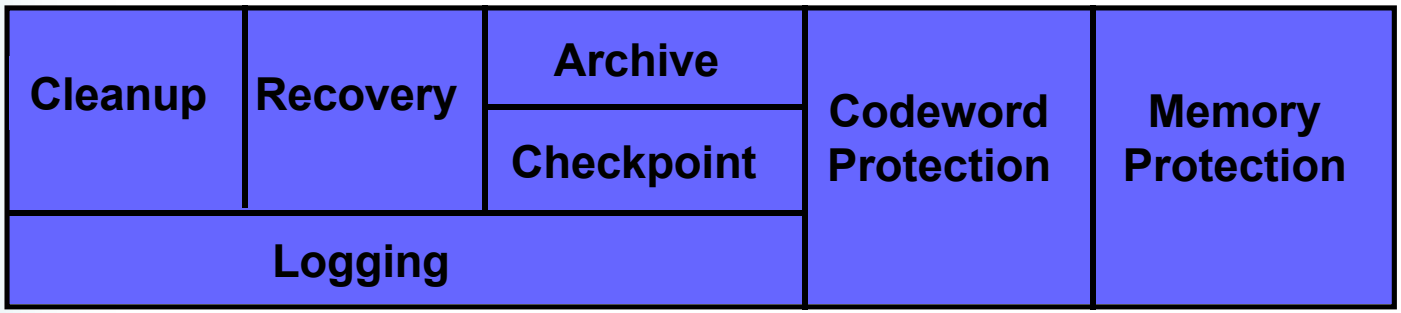

- Recovery from system failures
  - Recovers database to transaction consistent state
  - Fuzzy checkpointing, multi-level and post-commit logging
- Recovery from process failures
  - Process failures detected and transactions aborted
- Recovery from media failures
  - Creation of and recovery from database archives
- Detecting data corruption (due to application errors)
  - Codeword (one-word checksum) for each database page
  - Any page written to disk must match codeword
- Preventing data corruption (due to application errors)
  - Uses mprotect call to cause page faults on bad writes

Traditional Recovery Algorithms

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- **Each transaction writes the following to the log tail:**
  - Undo (before image) logs before update
  - Redo (after image) logs after update
- **Write-ahead logging**
  - Undo logs are flushed to disk before any affected page is written
  - Logs are flushed on transaction commit
- **Recovery in 3 phases**
  - Analysis - find winner and loser transactions
  - Redo - redo effects of completed transactions
  - Undo - undo effects of incomplete transactions
- **Checkpointing**
  - Flush dirty (updated) pages and note transaction information
  - Discard old part of the log

Recovery from System Failure

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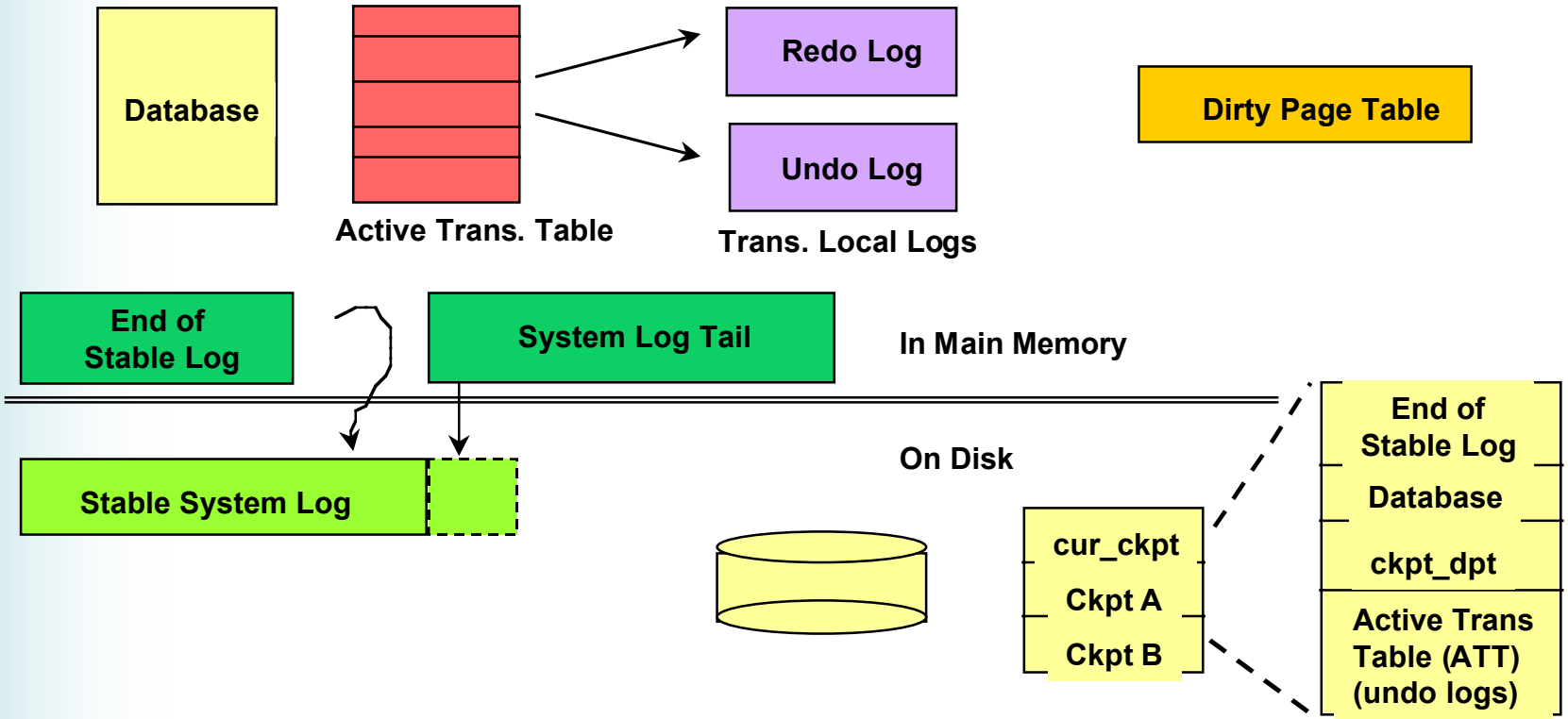
- Logs all updates on transaction commit/abort
- Writes periodic checkpoints of database state
- Performs recovery using checkpoint and logs



Datablitz Recovery Algorithm

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- **Repeat history**
- **Low Amount of disk I/O**
  - Redo logs are written to disk
  - No undo logs to disk normally
- **Ping-Pong Checkpointing Scheme**
  - Write to alternate disk copies on successive checkpoints
    - resilient to crashes during checkpointing
  - Only relevant undo logs written to disk when checkpointing
    - undo logs of transactions that are active at the end of the checkpoint
- **Fuzzy checkpoints**
  - Updates execute concurrently with checkpoints
    - e.g. No page latching during checkpoints
  - Only dirty pages written to disk during checkpoints
- **Single pass recovery algorithm**

Extended Logging Support

DataBlitz™

- **Logging support for high concurrency**
  - Multi-level logging
    - Physical undo during updates, logical undo afterward
  - Post-commit actions
    - Actions that cannot be rolled back (e.g. freeing storage space)
- **Support for user-defined operation logging**
- **Time stamp recovery**
  - Recover the database to a transaction-consistent point in the past
- **Turn redo logging off**
  - Support atomic transactions without requiring them to be durable

Codeword Protection

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- When codeword protection is turned on for a database, a parity-based checksum (codeword) is maintained for each page, and updates performed through DataBlitz update the checksum.
- The integrity of a page can be tested by this checksum by detecting errors, such as writes that did not use the DataBlitz interface, and random writes by means of bad application pointers.
- The integrity of a page is always tested before it is written to disk, so the disk copy is never corrupted.
- The user can also request "codeword audits" at other times.

Memory Protection Support

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- This allows pages to be protected using the UNIX system call *mprotect().*
- Pages are unprotected when written, and reprotected on transaction commit.
- While the unprotect and reprotect are slow (by DataBlitz standards), memory protection can be very useful for debugging, for read-only databases, and for databases with relatively low update rates.

Concurrency Control

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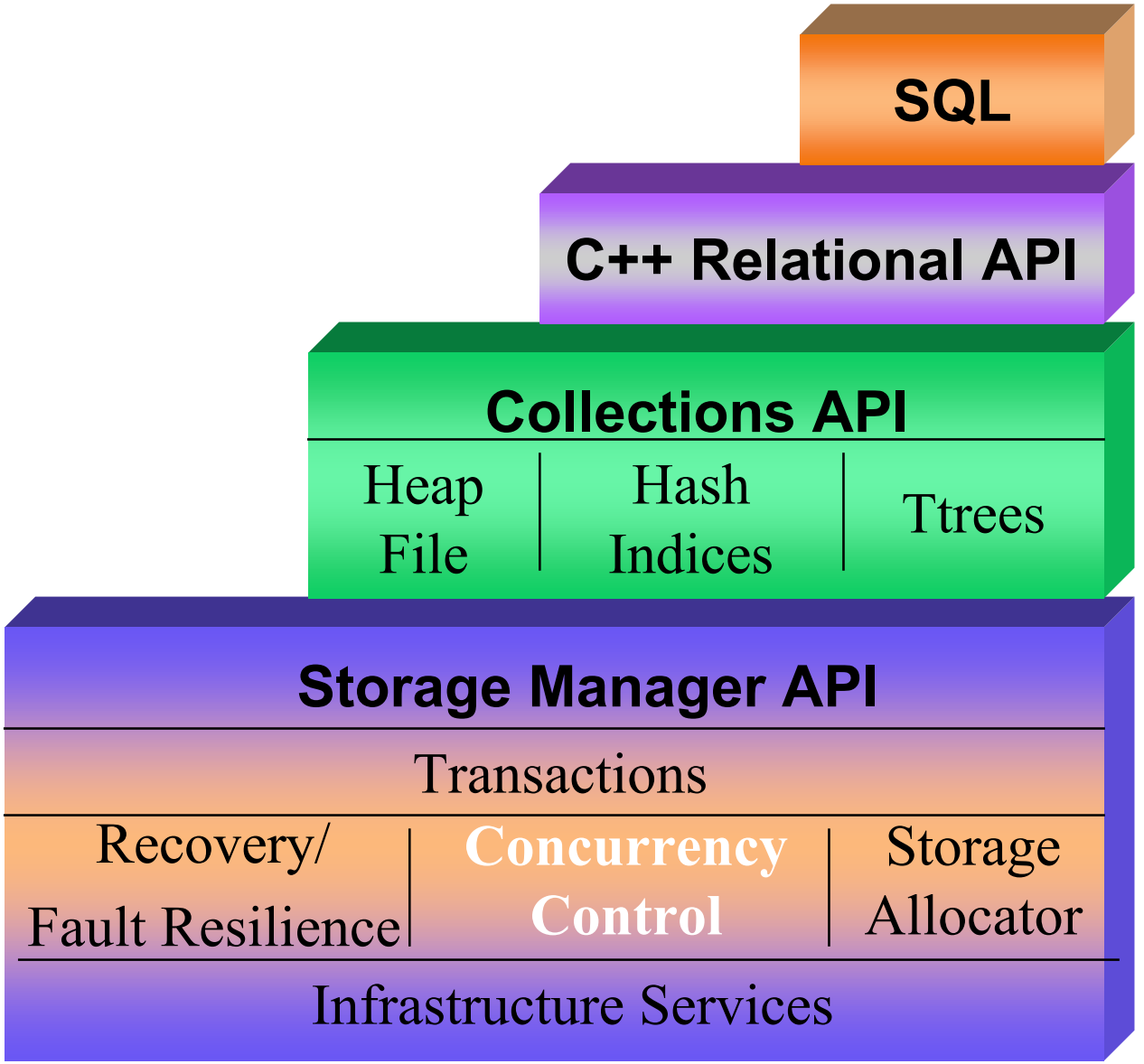

Concurrency Control

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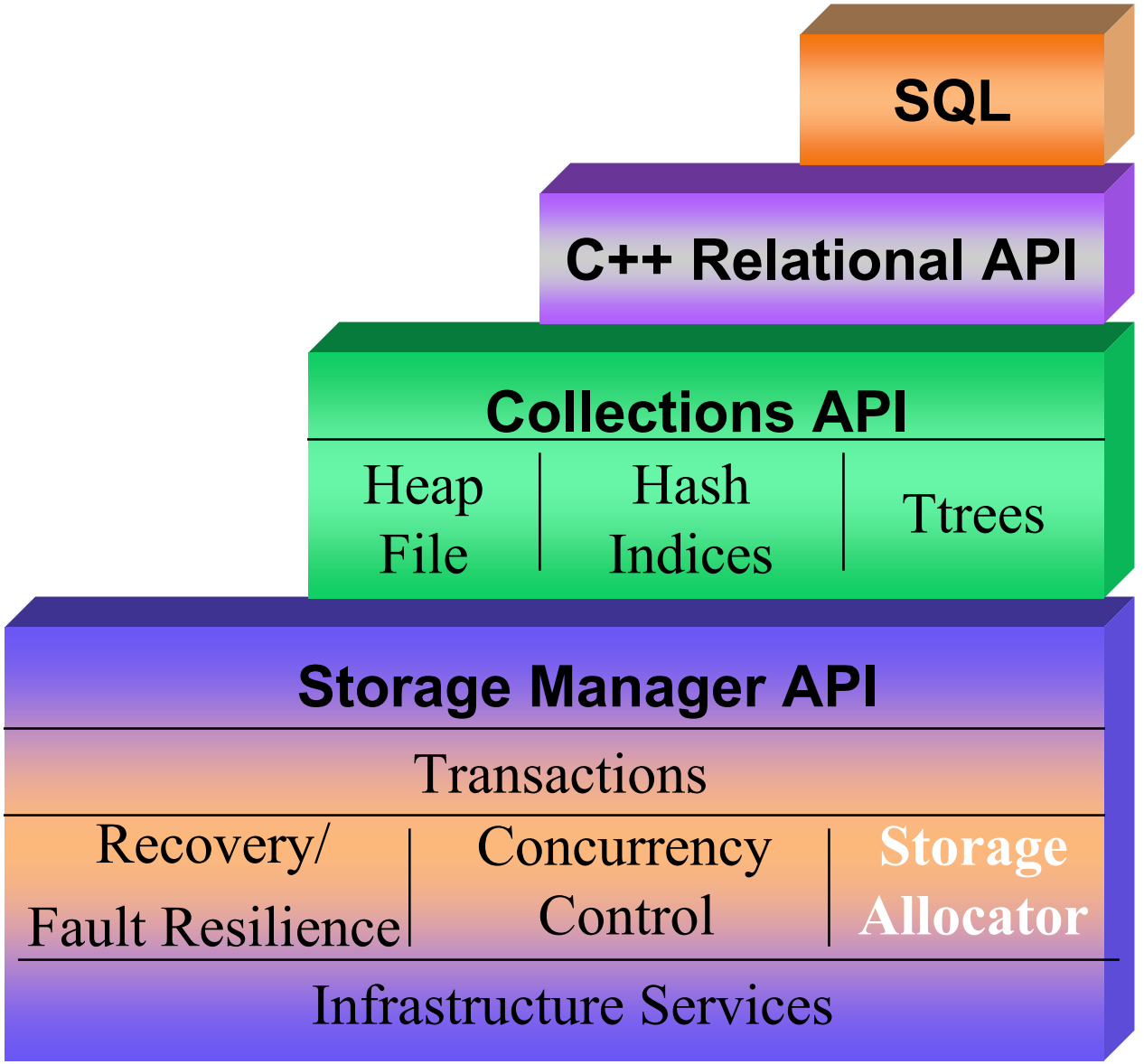
Lock Table	Shared Mutexes
Lock Manager	Exclusive Mutexes

- **Fast recoverable Mutexes**
  - Operating System semaphores are too expensive
  - Mutexes are implemented in user space for speed (e.g. spin locks)
  - Algorithms provided to detect a failed process holding a mutex
- **Lock manager**
  - Fine-grained locking (read/write/intention)
  - Supports lock upgrades/downgrades
  - Lock table used to obtain named locks with scalable latching

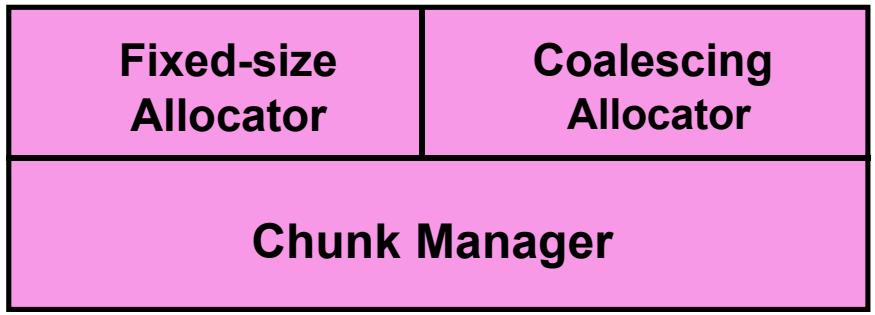
Storage Allocator

DataBlitz™

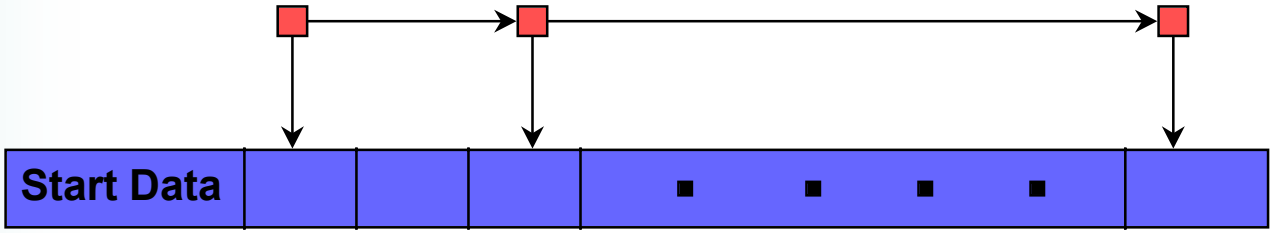


Storage Allocator

DataBlitz™



Chunk = collection of segments



Segment = contiguous, page-aligned space

- Chunks can have different recovery characteristics (zeroed memory, persistent memory)
- Control data stored separately from data
  - Reduces probability of corruption due to stray application pointers

Storage Allocator

DataBlitz™

- BlzPtrs
  - Database file plus offset
  - Enables database files to be mapped anywhere in the address space of a process
  - Enables database files to be resized
  - Size of database can exceed virtual address space of processes (e.g., 32-bit machines)
- Multiple Storage Allocators
  - Fixed-size allocator
  - Variable size allocator
    - Exact fit
    - Coalesce adjacent free blocks

Transactions

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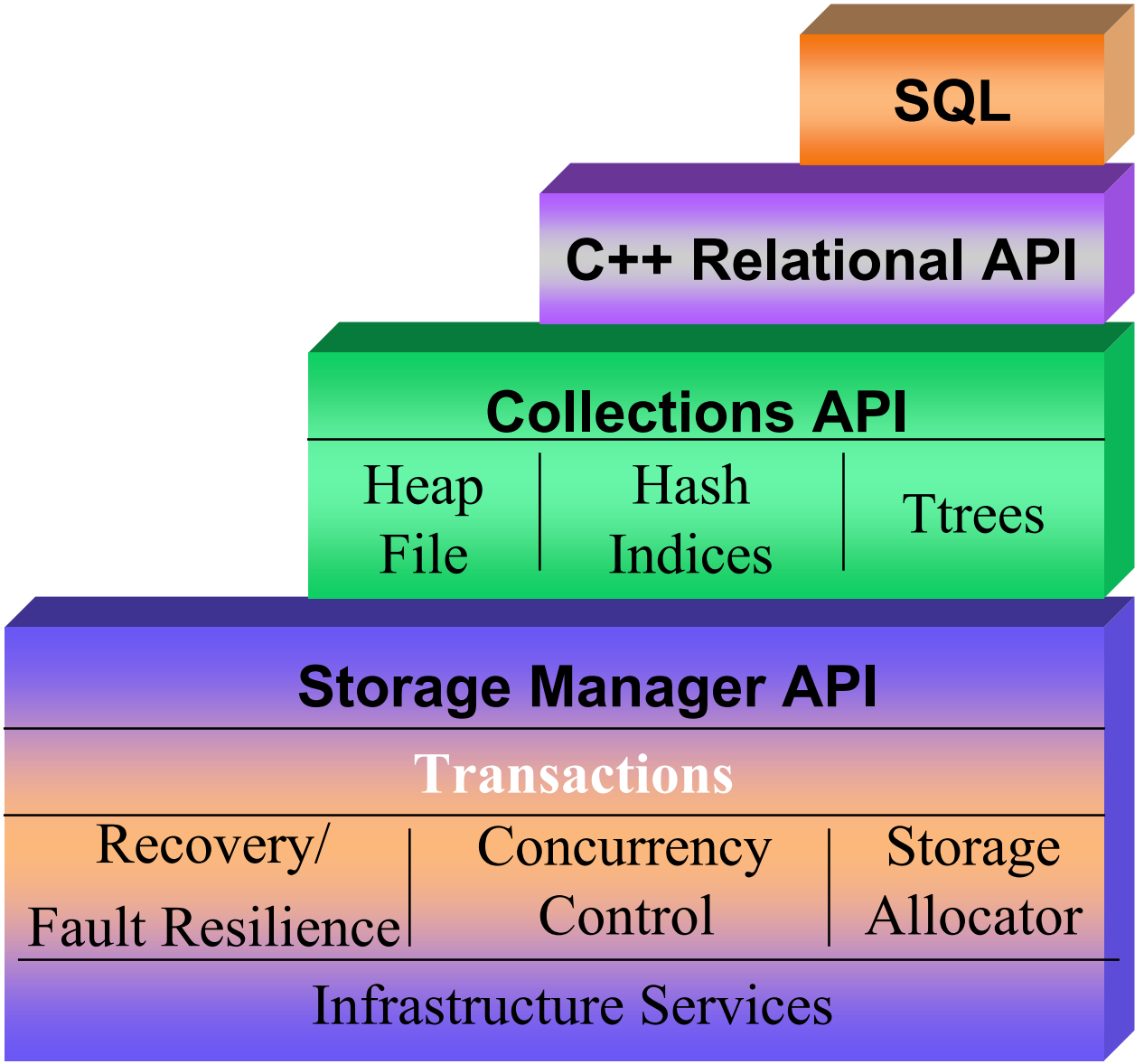

Transactions

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Full Transaction Semantics

- Transaction commit, abort, and save point interfaces provide fault tolerance through internal locking and logging facilities which deliver (A)tomicity, (C)onsistency, (I)solation, and (D)urability properties.
- Use of transactions greatly eases the task of implementing systems that handle concurrent programs, and a variety of failures, while maintaining the integrity of vital data.

Heap File

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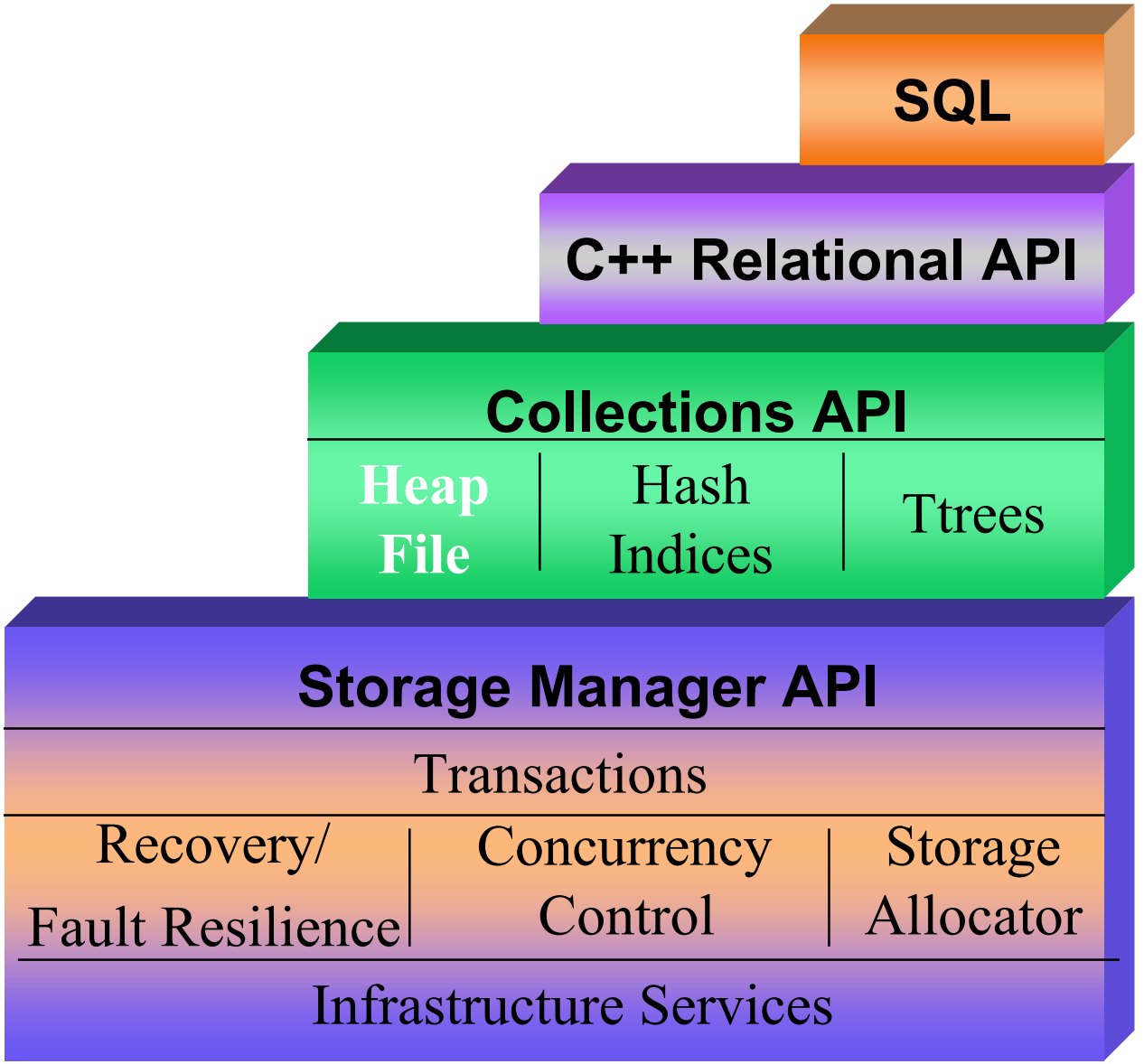

Heap File

DataBlitz™

- The heap file is abstraction for handling a large number of fixed-length data items, and is implemented as a thin layer on top of the Storage Manager allocator.
- In addition to insertion and deletion, the heap file supports locking and an unordered scan of items.
- Item locks are obtained transparently when items are inserted, deleted, updated or scanned.

Extendible Hash Indices

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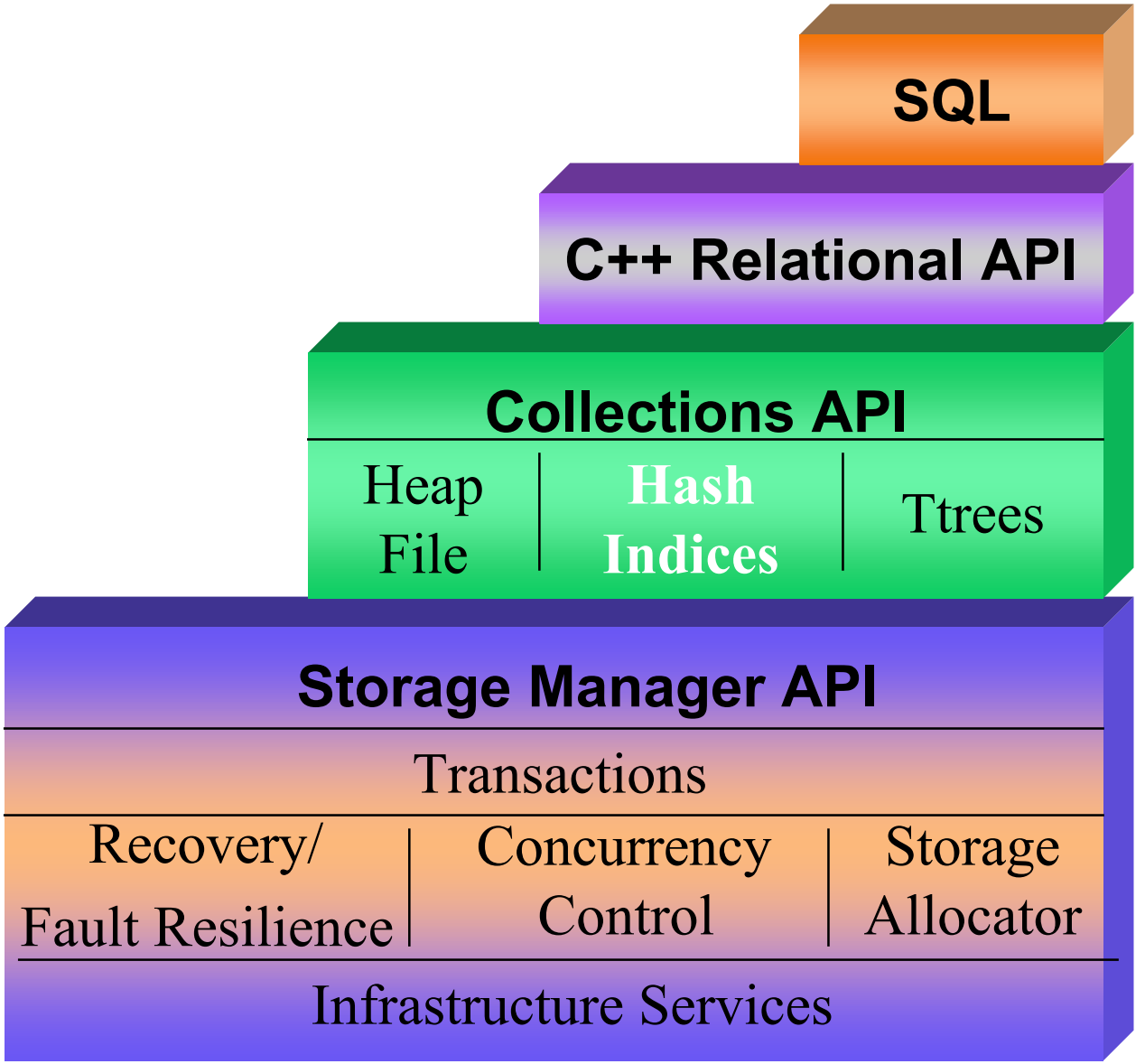
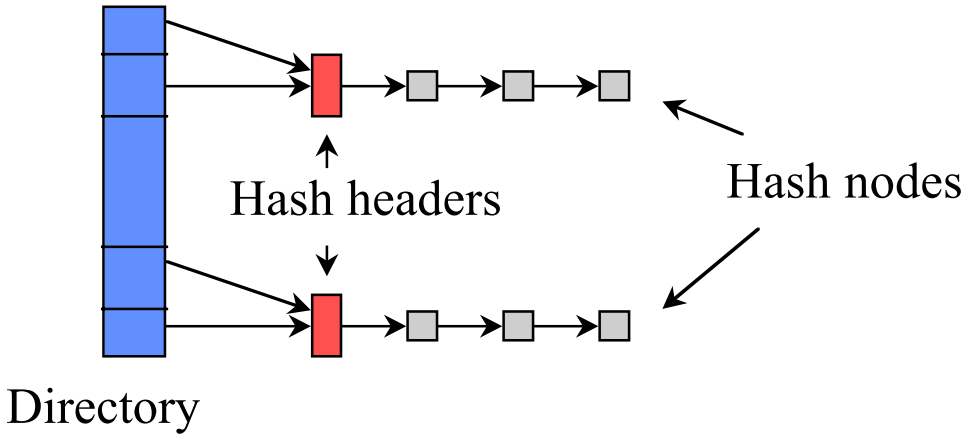


Extendible Hash Indices

DataBlitz™

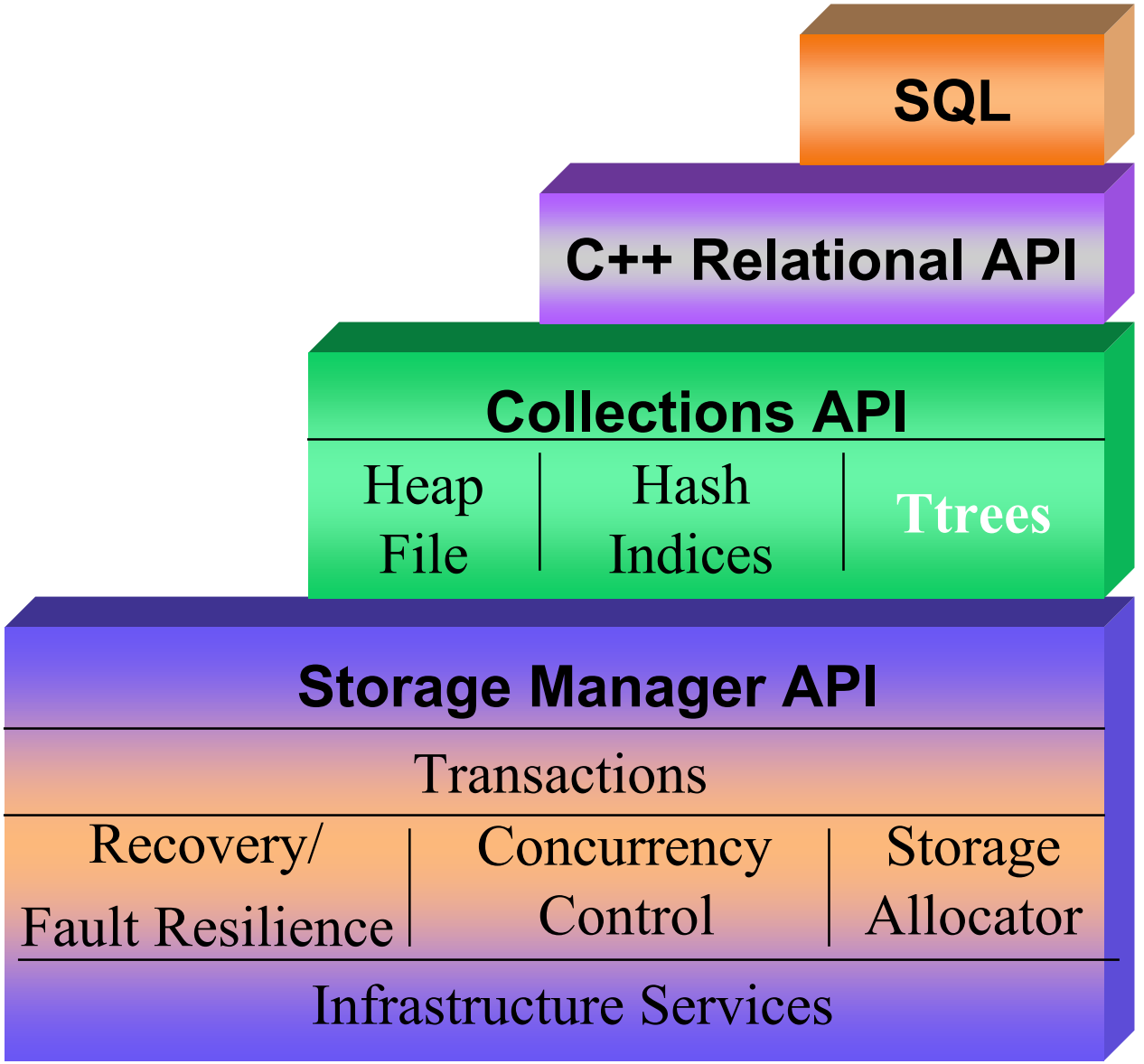
DataBlitz offers both fixed and extended hash indices:

- **Directory grows with number of elements in hash index**
- **Inserts/deletes/scans involving different buckets can execute concurrently**
- **Directory can grow while inserts/deletes/lookups continue**
- **Ideal for point look-ups on data**
- **Supports varying degrees of isolation (e.g., cursor stability, phantom)**



Ttree Indices

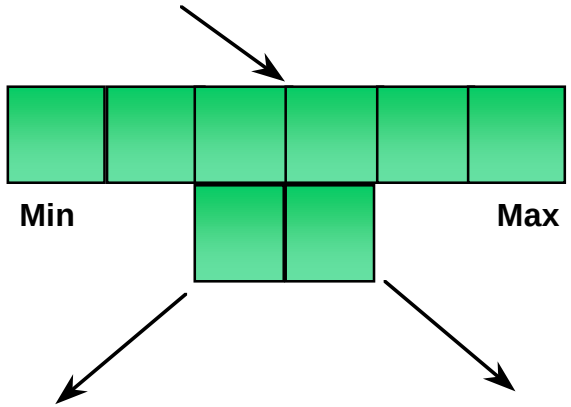
DataBlitz™



Ttrees Indices

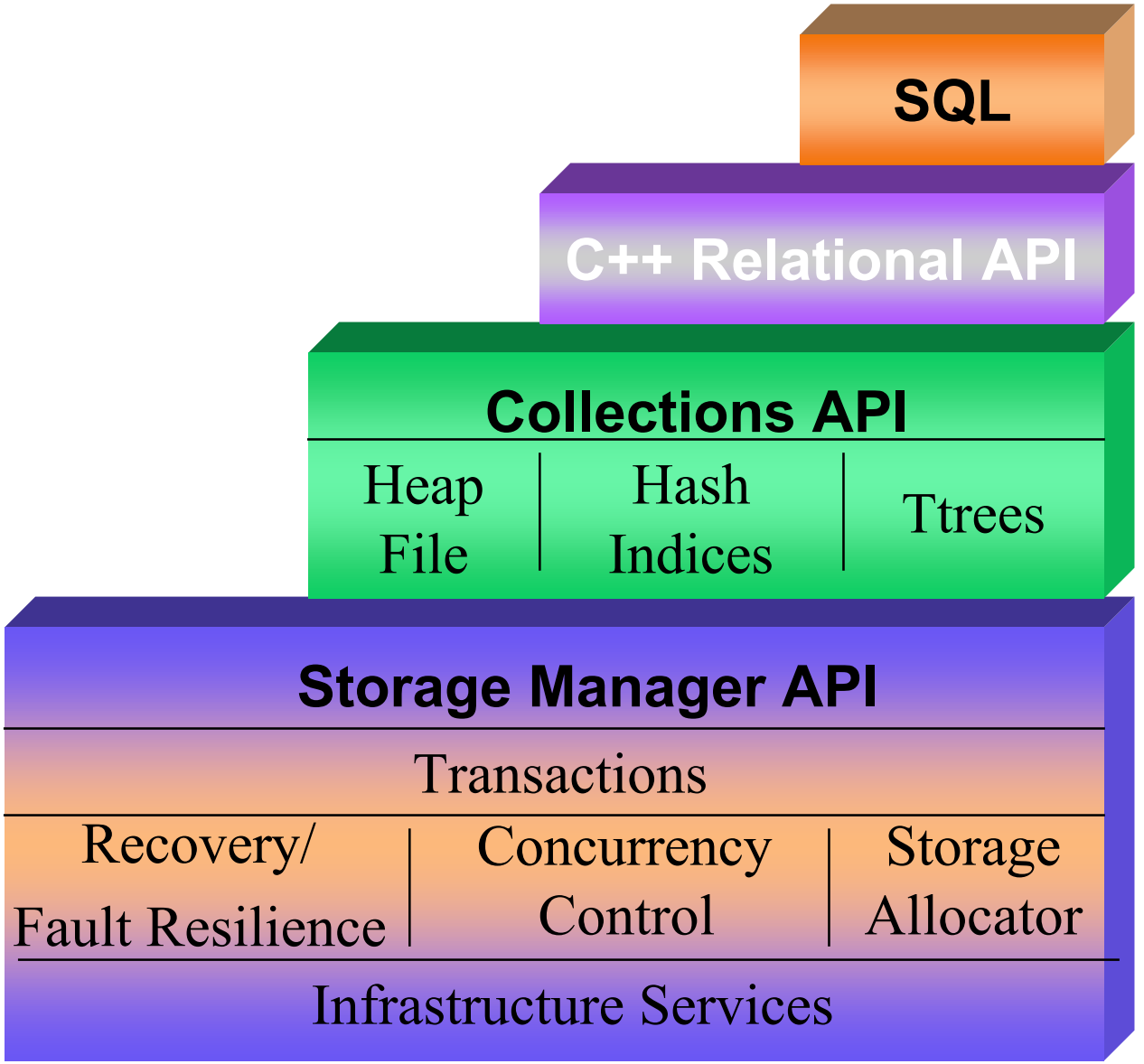
DataBlitz™

- Ordered structure, like an AVL or height balanced tree
- Multiple keys per node
- Ideal for ordered scans over data
- Supports varying degrees of isolation (e.g. Cursor Stability, Phantom)



C++ Relational API

DataBlitz™



C++ Relational API

DataBlitz™

Views	
DML	DDL (SQL)

- Supports Hash and Ttree indices on an arbitrary subset of attributes
- Predicate-based scans on tables are supported
- Materialized joins and one-to-many relationships
- Enforces referential integrity constraints
- Wide variety of field types
  - Variable length fields
  - Date, Time, Decimal, and other numeric types
  - Null values
- Views: simple select project joins on base tables
- Supports different isolation levels (e.g. Cursor Stability, Phantom)
- Schema/Data import/export

SQL

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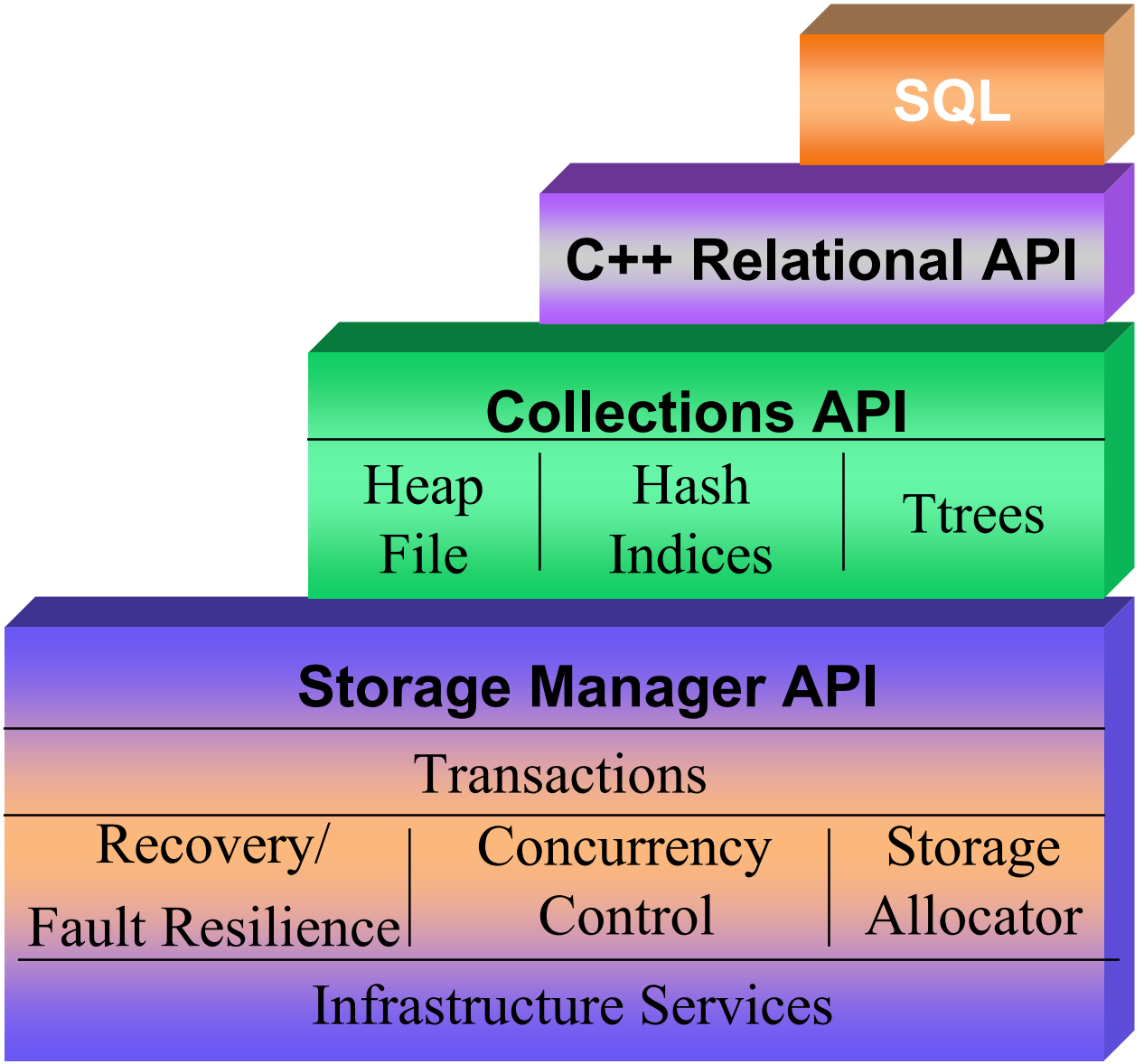


SQL/JDBC/ODBC Interfaces

DataBlitz™

- DataBlitz builds upon the Dharma/SQL engine to provide SQL, JDBC, and ODBC support
- The Dharma/SQL engine provides feature and performance parity with leading DBMS vendors
- The Dharma/SQL engine is production-proven with a large installed customer base
- Standards conformance
  - Complete SQL 92 entry level support
  - ODBC 3.0 (core, level1 and most level 2 APIs)
  - JDBC 1.2

SQL Interface Features

DataBlitz™

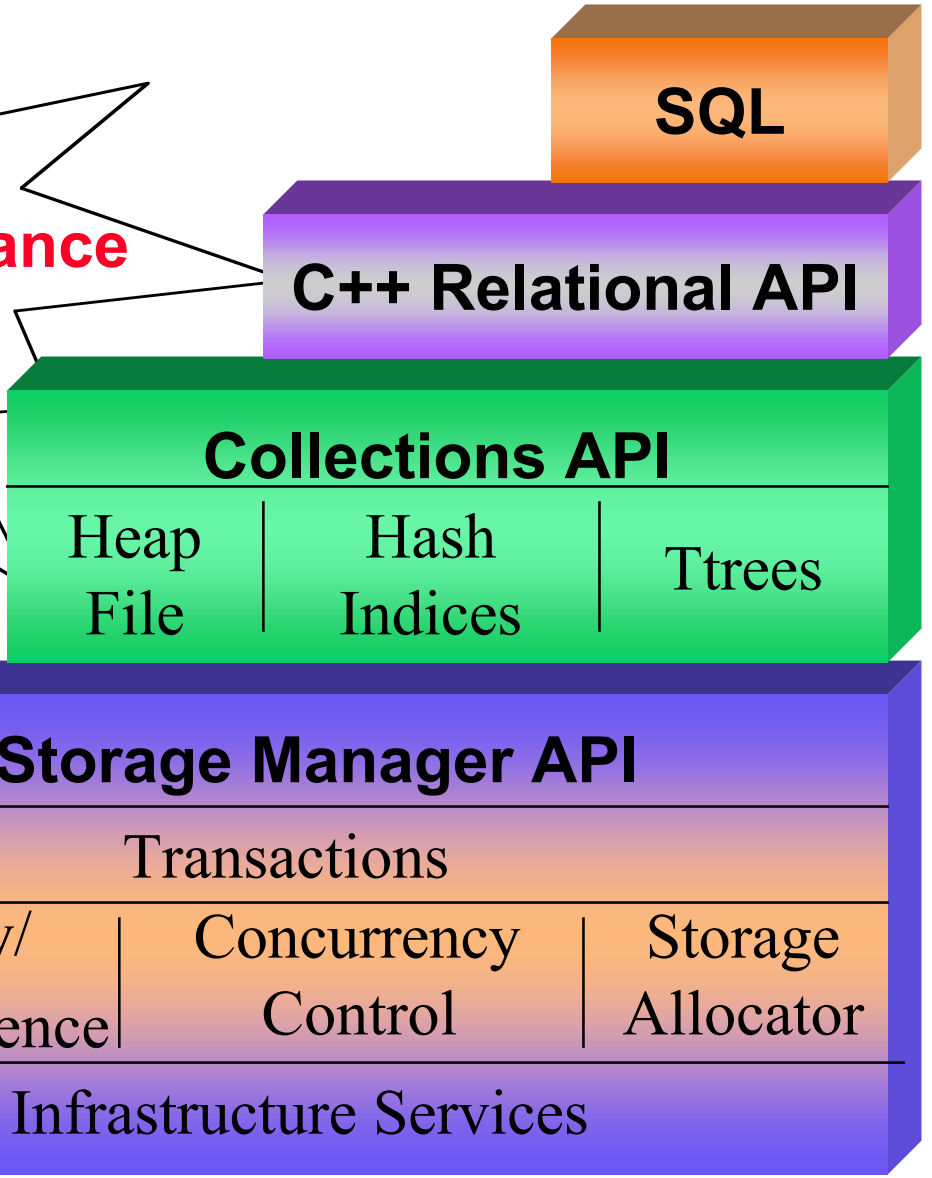
- Query Optimization
  - Statistics and cost-based optimization (e.g. query selectivity, table cardinality, histograms)
  - Join order/method selection for complex queries
  - Query rewrite algorithms for nested queries
  - Join hints for influencing query execution plans
- Run-time optimizations
  - Compiled/cached SQL for repeated queries
  - Multi-tuple fetches/appends
  - Tuple-level locking support
  - Execution plan data pipelining
- Complete SQL-92 support plus
  - Date/time/interval types
  - variable length character strings
  - Nested queries
  - Transaction isolation levels
  - Recursive views
  - Schema manipulation statements
- Java support
  - Java stored procedures
  - Java triggers
  - JDBC 1.2

High Performance Modular Architecture

DataBlitz™

DataBlitz provides:

- the highest performance
- the most reliability
- the most flexibility

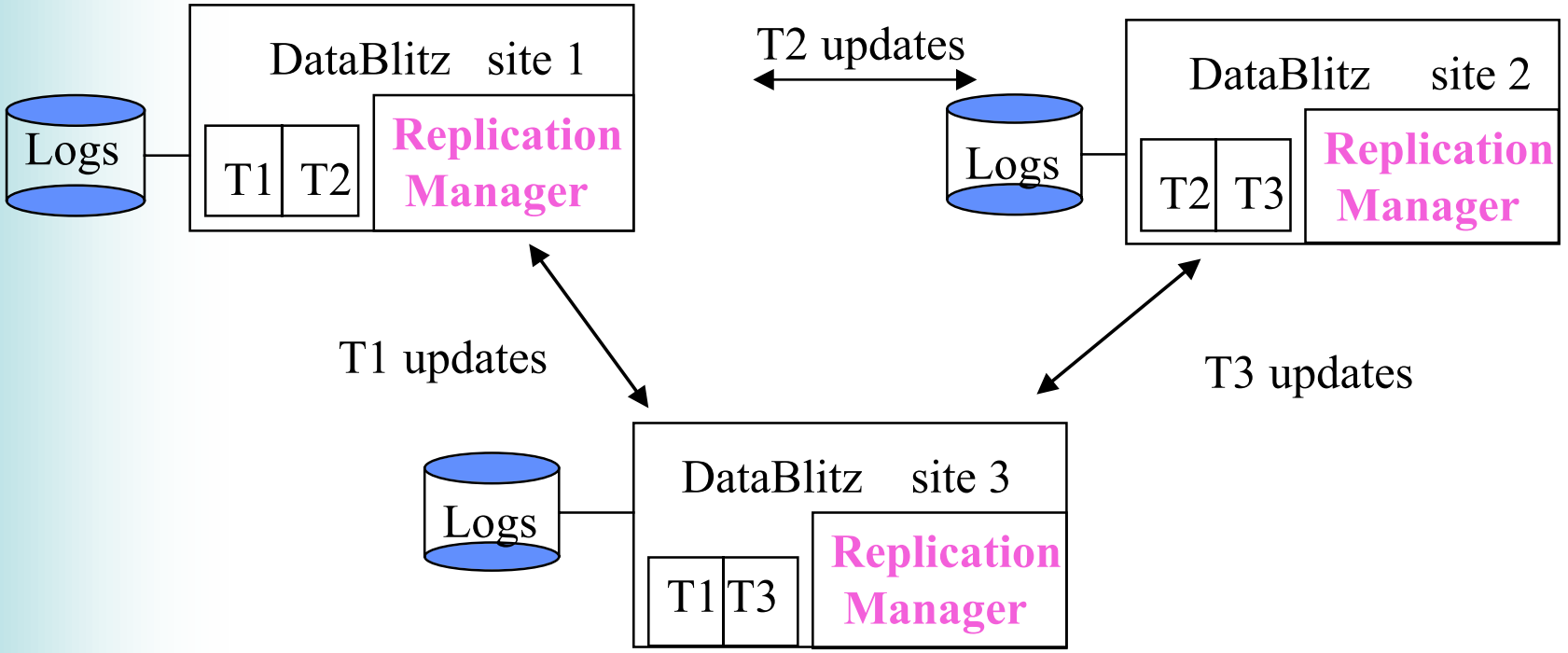


Data Replication

DataBlitz™

- **Data replication can help improve**
  - System availability (data still available even if site fails)
  - System performance (replicated data can be accessed locally)
- **DataBlitz supports "update anywhere" replication model**
  - Data is replicated at the granularity of tables
  - Any site can update/access replicas without consulting other sites
  - Updates propagated to replicas asynchronously using logs
  - Conflicts between updates resolved using timestamps
- **The DataBlitz replication manager guarantees that**
  - Every table update is eventually propagated to every table replica
  - Table replicas converge to identical state when system is quiesced

Data Replication



Updates performed at site 1 via T1 propagate to site 3.
Updates performed at site 2 via T2 propagate to site 1.
Updates performed at site 3 via T3 propagate to site 2.

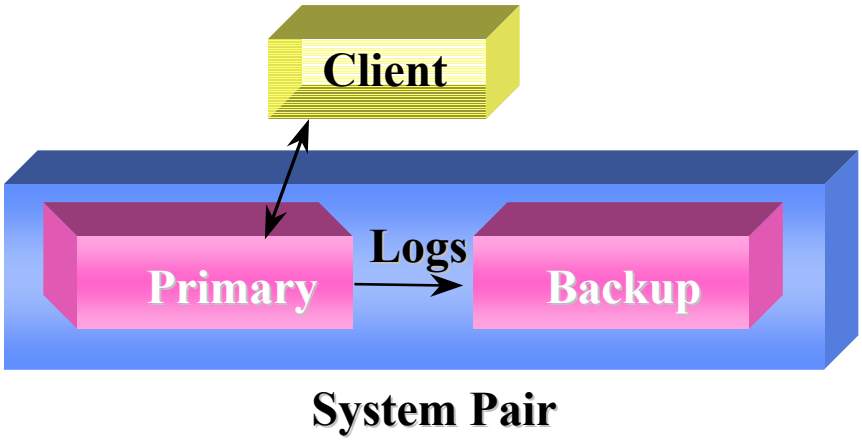
The DataBlitz replication protocol ensures that all sites converge to the same state.

Data Replication

DataBlitz™

- **Handling conflicting updates**
  - Update with largest timestamp wins
  - Timestamp and update information for loser updates output to a file
- **Handling "normal" site failures**
  - After site recovers, it resumes propagating updates and applying updates to replicated tables (shipped to it from other sites)
- **Handling extended outages**
  - Logs for certain updates to be applied at recovering site may have been truncated
  - After site recovers, it merges the most recent copy of the table from an operational site with its own copy of the table

Hot Spare Using Replication



- Hot spare is the backup or secondary system
  - Keeps in sync with the primary via logs
- Higher availablity as the backup takes over when the primary fails
- Once the backup has taken over, it becomes the primary. The original primary would then become the secondary.

Additional DataBlitz Features

DataBlitz™

- Thread-safe
  - Concurrent thread access to DataBlitz
- True 64-bit architecture support
  - Database files greater than 4GB
- Configurability
  - Can turn features on and off (e.g., logging, locking)
  - Can fine tune various system parameters (e.g. number of chunks, maximum database files, active transaction table size)
- Bulk loading
  - Extremely fast data loading while locking and logging are disabled

DataBlitz System Servers

DataBlitz™

- Root server
  - Initializes system structures (e.g. lock table)
- Checkpoint server
  - Checkpoints database files periodically
- Flush server
  - Writes logs to disk asynchronously
- Cleanup server
  - Detects failed processes and co-ordinates cleanup
- Recovery server
  - Recovers a database in response to data corruption
- Mlock server
  - Memory locks performance critical database files in memory

DataBlitz System Tools

- **Data Migration**
  - Tools for transfering schema information or table data between databases and files
  - Tools for transfering relational data in tabular form
- **RelDDL**
  - A stand-alone tool used for data definitions in standard SQL syntax
- **Administrative GUI**
  - Monitor system resource usage
    - **Storage space (segments, bytes allocated in a chunk)**
    - **Servers, processes, threads**
    - **Transactions, locks**
  - Perform archives/restore
  - Change configuration parameters
- **Archive/Restore**
  - C++ API and command line interpreter for database backups
- **Resource Monitoring/Checking**
  - C++ API and command line interpreter for checking usage of resources

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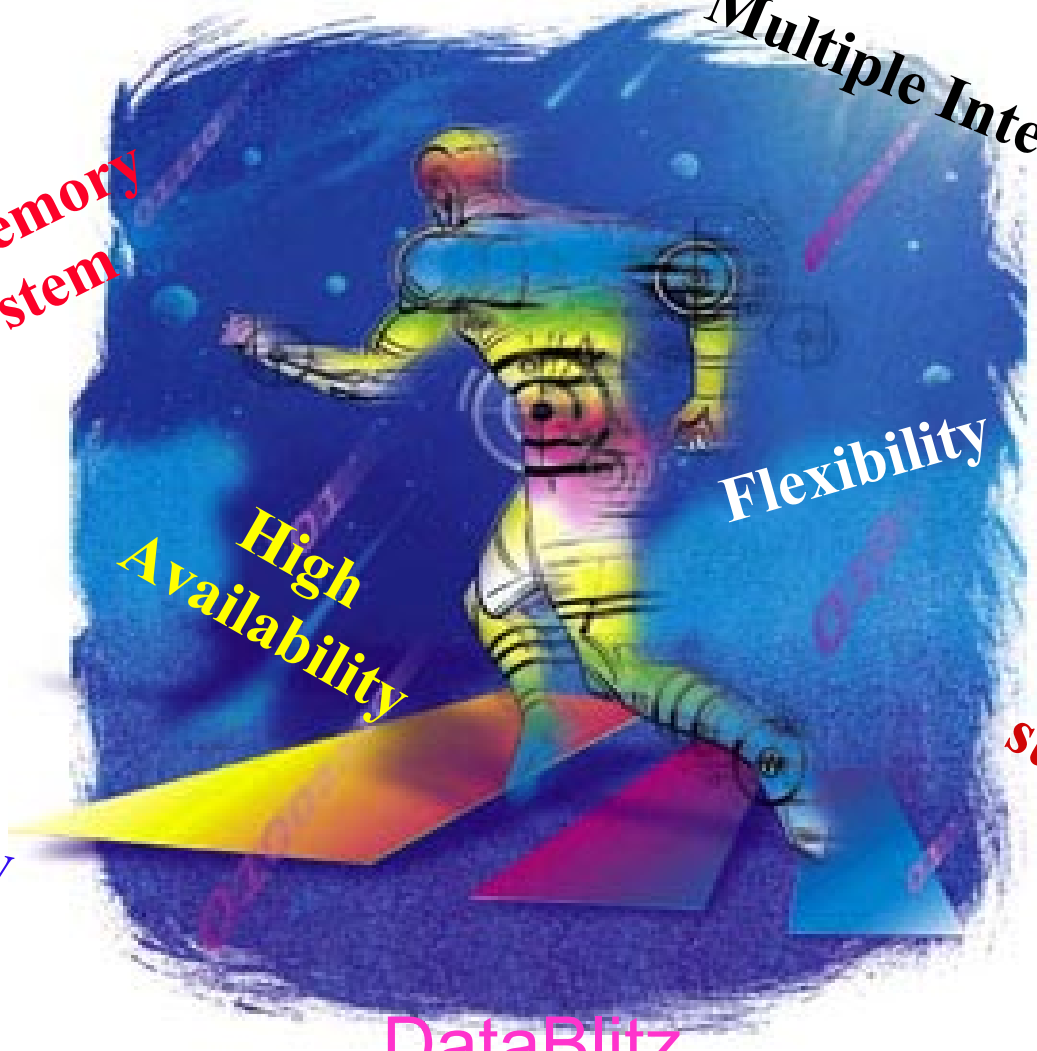

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Main Memory DataBase System