Introduction to Tokyo Products

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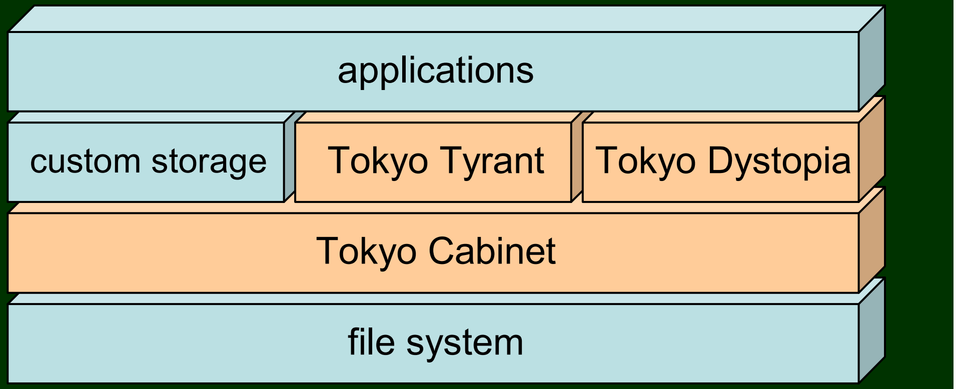
Tokyo Products

- Tokyo Cabinet
  - database library
- Tokyo Tyrant
  - database server
- Tokyo Dystopia
  - full-text search engine



- open source
  - released under LGPL
- powerful, portable, practical
  - written in standard C, optimized to POSIX

Tokyo Cabinet

- database library -

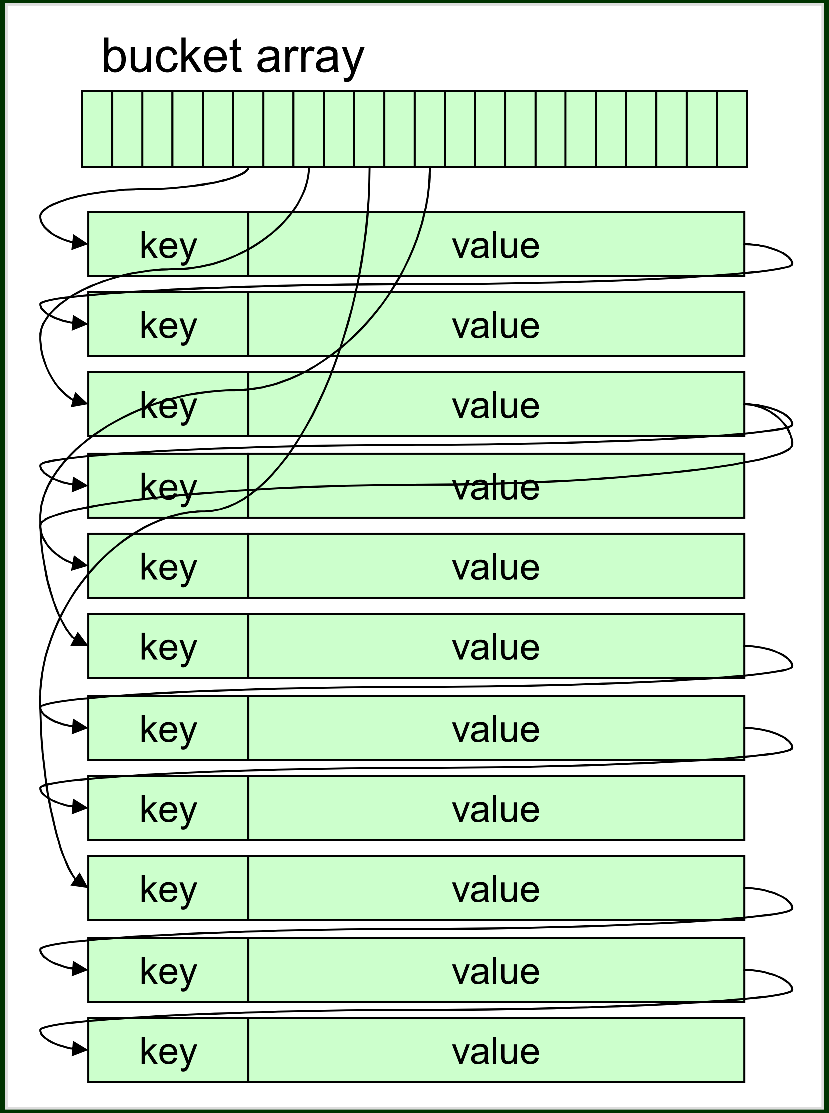
Features

- modern implementation of DBM
  - Key/value database
    - e.g.) DBM, NDBM, GDBM, TDB, CDB, Berkeley DB
  - simple library = process embedded
  - Successor of QDBM
    - C99 and POSIX compatible, using Pthread, mmap, etc...
    - Win32 porting is work-in-progress
- high performance
  - insert: 0.4 sec/1M records (2,500,000 qps)
  - search: 0.33 sec/1M records (3,000,000 qps)

- **high concurrency**
  - multi-thread safe
  - read/write locking by records
- **high scalability**
  - hash and B+tree structure = O(1) and O(log N)
  - no actual limit size of a database file (to 8 exabytes)
- **transaction**
  - write ahead logging and shadow paging
  - ACID properties
- **various APIs**
  - on-memory list/hash/tree
  - file hash/B+tree/array
- **script language bindings**
  - Perl, Ruby, Java, Lua, Python, PHP, Haskell, Erlang, etc...

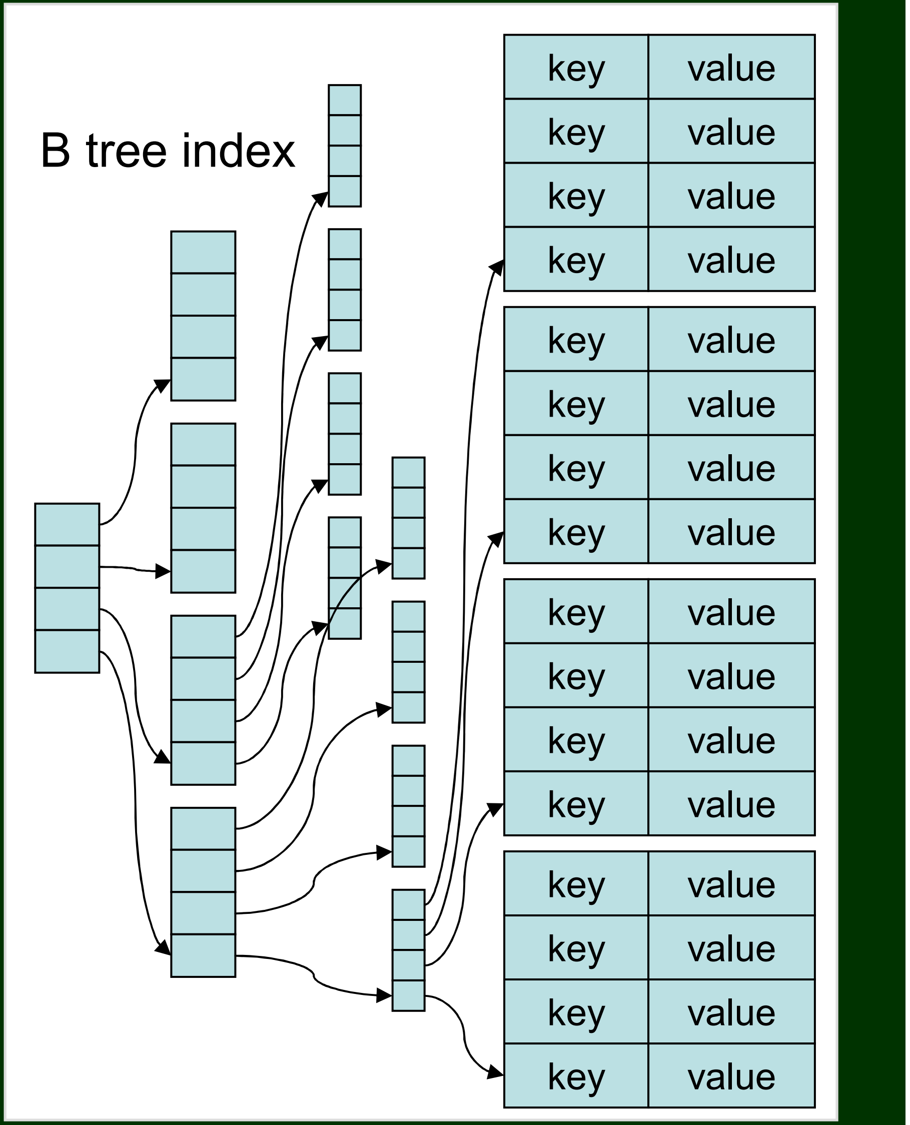
TCHDB: Hash Database

- static hashing
  - O(1) time complexity
- separate chaining
  - binary search tree
- free block pool
  - best fit allocation
- combines mmap and pwrite/pread
  - saves calling system calls
- compression
  - deflate(gzip)/bzip2/custom



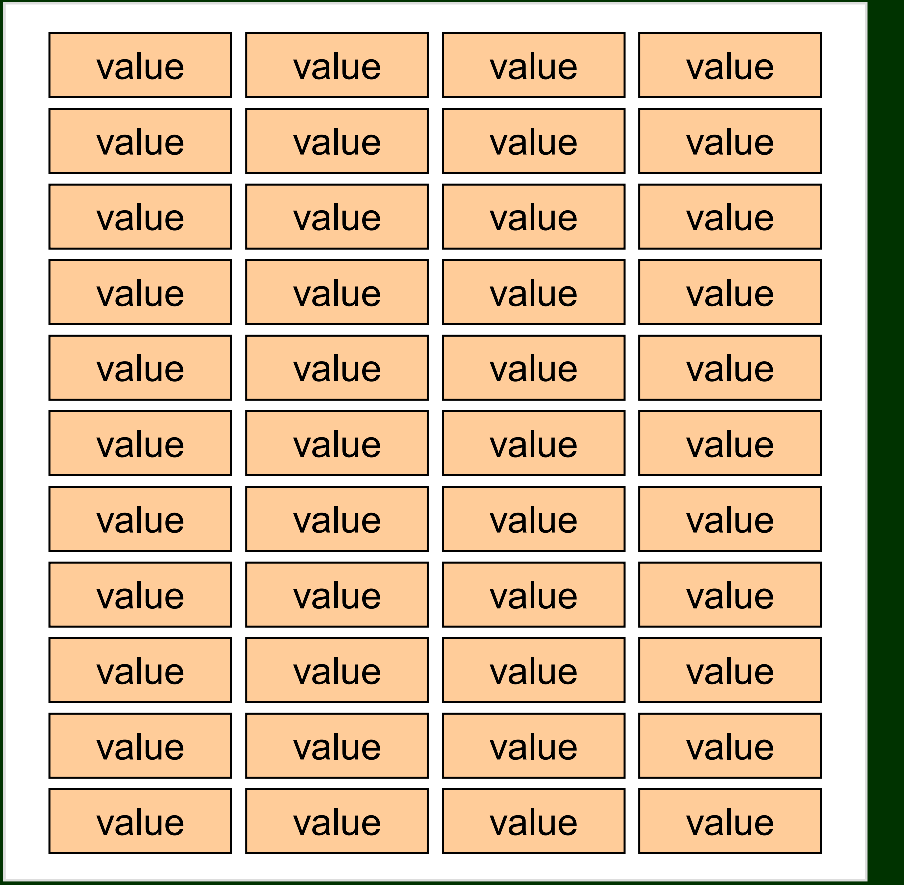
TCBDB: B+ Tree Database

- B+ tree
  - O(log N) time complexity
- page caching
  - LRU removing
  - speculative search
- stands on hash DB
  - records pages in hash DB
  - succeeds time and space efficiency
- custom comparison function
  - prefix/range matching
- cursor
  - jump/next/prev



TCFDB: Fixed-length Database

- array of fixed-length elements
  - O(1) time complexity
  - natural number keys
  - addresses records by power of key
- most effective
  - bulk load by mmap
  - no key storage per record
  - extremely fast and concurrent



value	value	value	value
value	value	value	value
value	value	value	value
value	value	value	value
value	value	value	value
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value	value	value	value
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value	value	value	value
value	value	value	value
value	value	value	value

On-memory Structures

- TCXSTR: extensible string
  - concatenation, formatted allocation
- TCLIST: array list (dequeue)
  - random access by index
  - push/pop, unshift/shift, insert/remove
- TCMAP: map of hash table
  - insert/remove/search
  - iterator by order of insertion
- TCTREE: map of ordered tree
  - insert/remove/search
  - iterator by order of comparison function

Other Mechanisms

- abstract database
  - common interface of 5 schema
    - on-memory hash, on-memory tree
    - file hash, file B+tree, file array
  - decides the concrete scheme on runtime
- remote database
  - network interface of the abstract database
  - yes, it's Tokyo Tyrant!
- miscellaneous utilities
  - string processing, filesystem operation
  - memory pool, encoding/decoding

Example Code

```c
#include <tcutil.h>
#include <tchdb.h>
#include <stdlib.h>
#include <stdbool.h>
#include <stdint.h>

int main(int argc, char **argv){

  TCHDB *hdb;
  int ecode;
  char *key, *value;

  /* create the object */
  hdb = tchdbnew();

  /* open the database */
  if(!tchdbopen(hdb, "casket.hdb", HDBOWRITER | HDBOCREAT)){
    ecode = tchdbecode(hdb);
    fprintf(stderr, "open error: %s¥n", tchdberrmsg(ecode));
  }

  /* store records */
  if(!tchdbput2(hdb, "foo", "hop") ||
     !tchdbput2(hdb, "bar", "step") ||
     !tchdbput2(hdb, "baz", "jump")){
    ecode = tchdbecode(hdb);
    fprintf(stderr, "put error: %s¥n", tchdberrmsg(ecode));
  }

  /* retrieve records */
  value = tchdbget2(hdb, "foo");
  if(value){
    printf("%s¥n", value);
    free(value);
  } else {
    ecode = tchdbecode(hdb);
    fprintf(stderr, "get error: %s¥n", tchdberrmsg(ecode));
  }
```

```c
  /* traverse records */
  tchdbiterinit(hdb);
  while((key = tchdbiternext2(hdb)) != NULL){
    value = tchdbget2(hdb, key);
    if(value){
      printf("%s:%s¥n", key, value);
      free(value);
    }
    free(key);
  }

  /* close the database */
  if(!tchdbclose(hdb)){
    ecode = tchdbecode(hdb);
    fprintf(stderr, "close error: %s¥n", tchdberrmsg(ecode));
  }

  /* delete the object */
  tchdbdel(hdb);

  return 0;
}
```

Tokyo Tyrant

- database server -

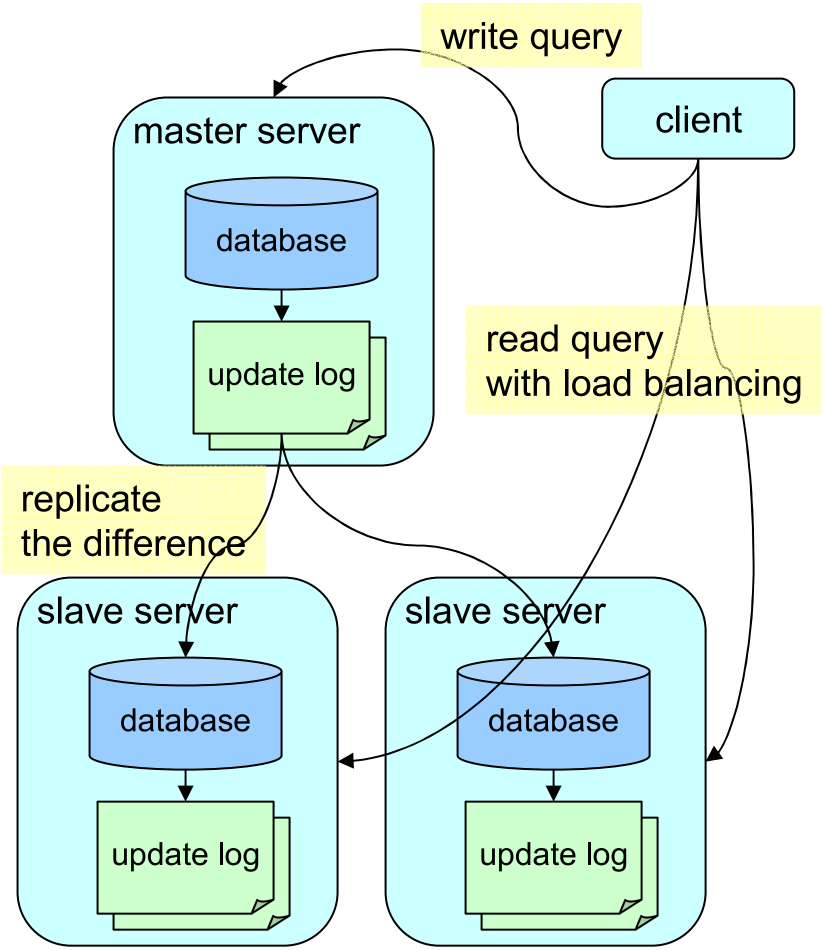
Features

- network server of Tokyo Cabinet
  - client/server model
  - multi applications can access one database
  - effective binary protocol
- compatible protocols
  - supports memcached protocol and HTTP
  - available from most popular languages
- high concurrency/performance
  - resolves "c10K" problem with epoll/kqueue
  - 17.2 sec/1M queries (58,000 qps)

- high availability
  - hot backup and update log
  - asynchronous replication between servers
- various database schema
  - using the abstract database API of Tokyo Cabinet
- effective operations
  - no-reply updating, multi-record retrieval
  - atomic increment
- Lua extension
  - defines arbitrary database operations
  - atomic operation by record locking
- pure script language interfaces
  - Perl, Ruby, Java

Asynchronous Replication

master and slaves (load balancing)



write query

client

master server

database

update log

read query
with load balancing

replicate
the difference

slave server

database

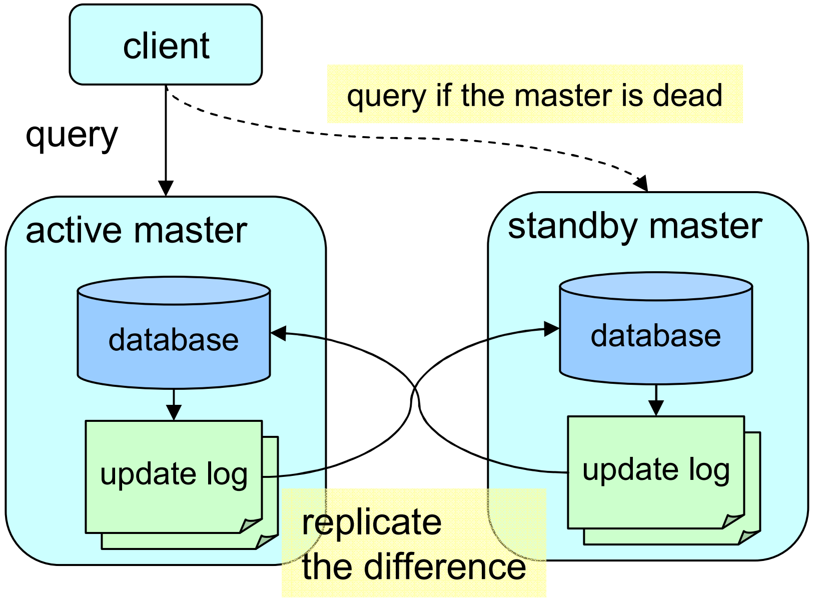
update log

slave server

database

update log

dual master (fail over)



client

query

query if the master is dead

active master

database

update log

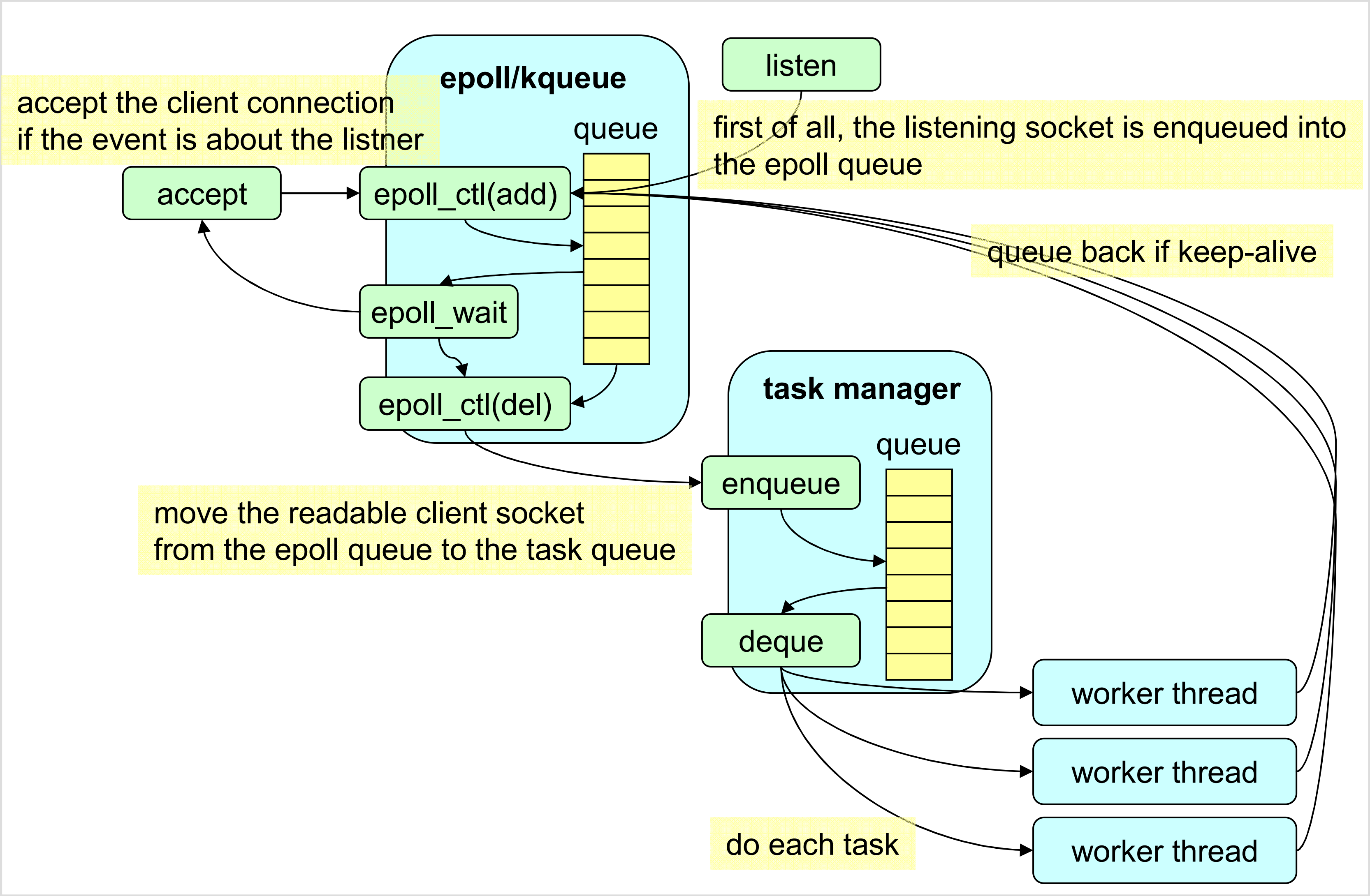
standby master

database

update log

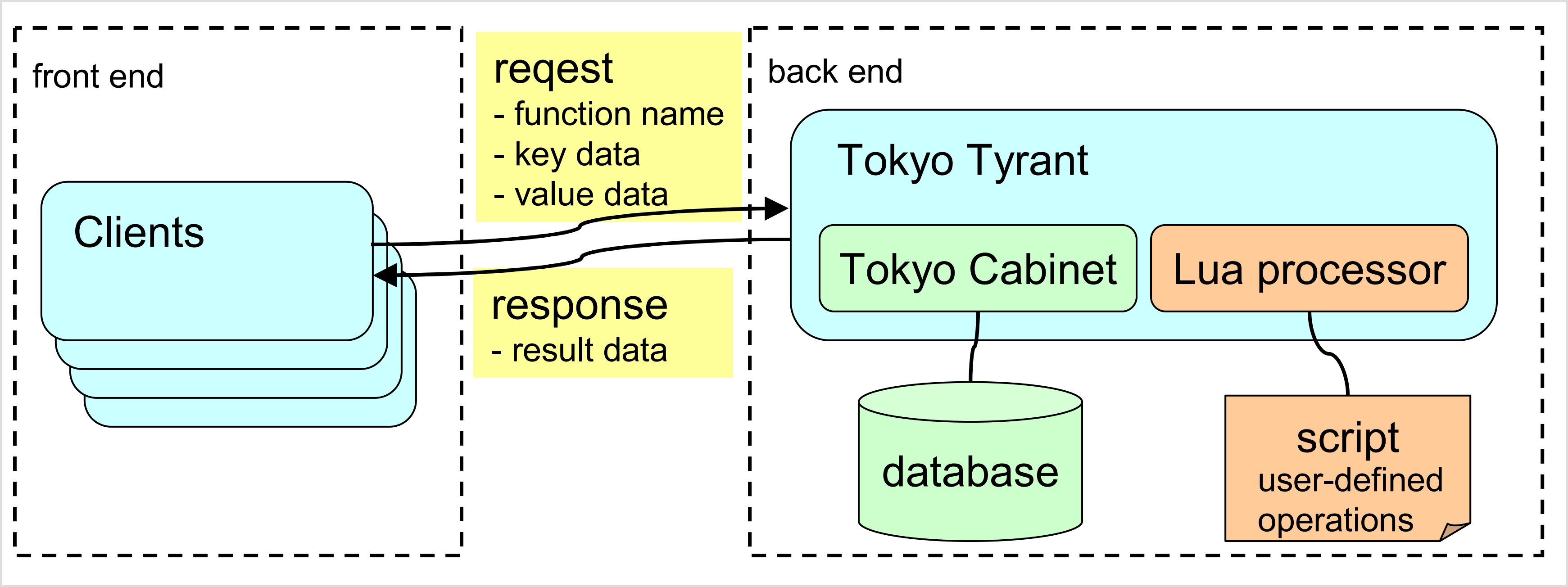
replicate
the difference

Thread Pool Model



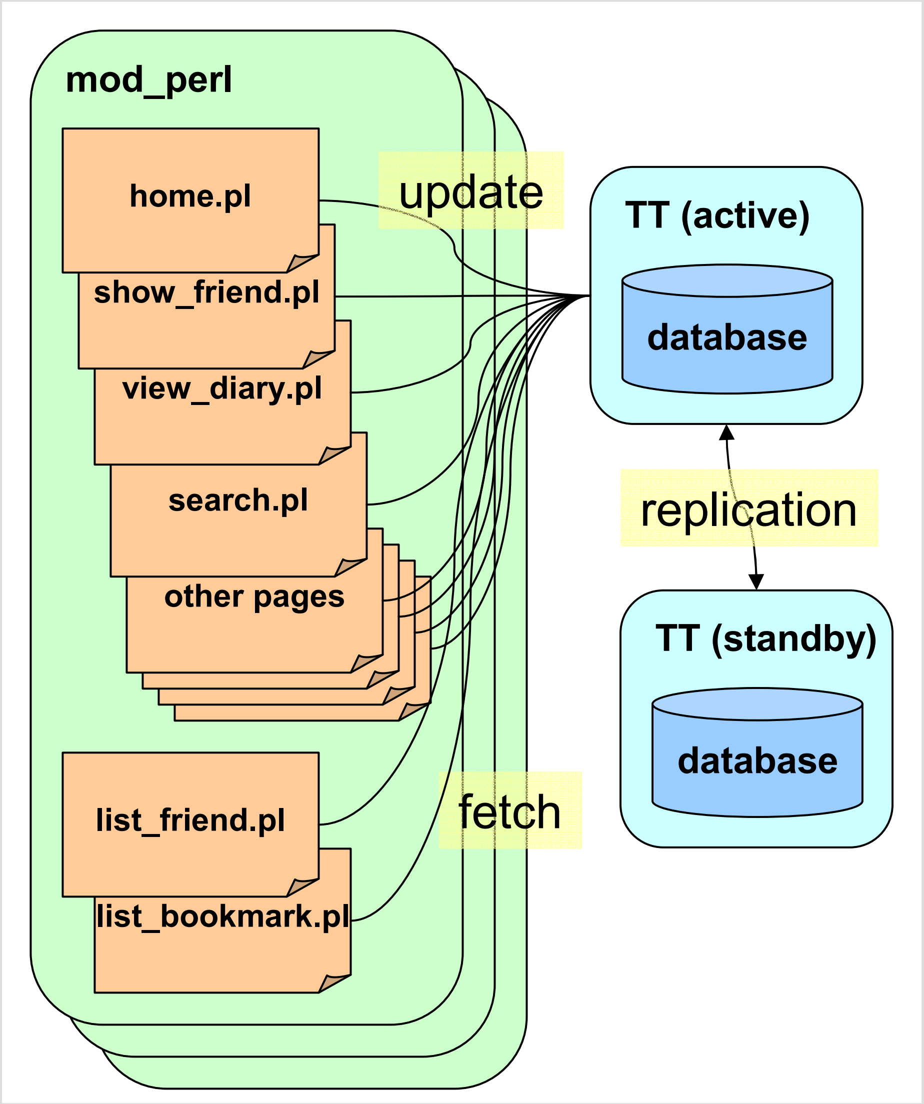
Lua Extention

- defines DB operations as Lua functions
  - clients call each giving function name and record data
  - the server returns the return value of the function
- options about atomicity
  - no locking / record locking / global locking



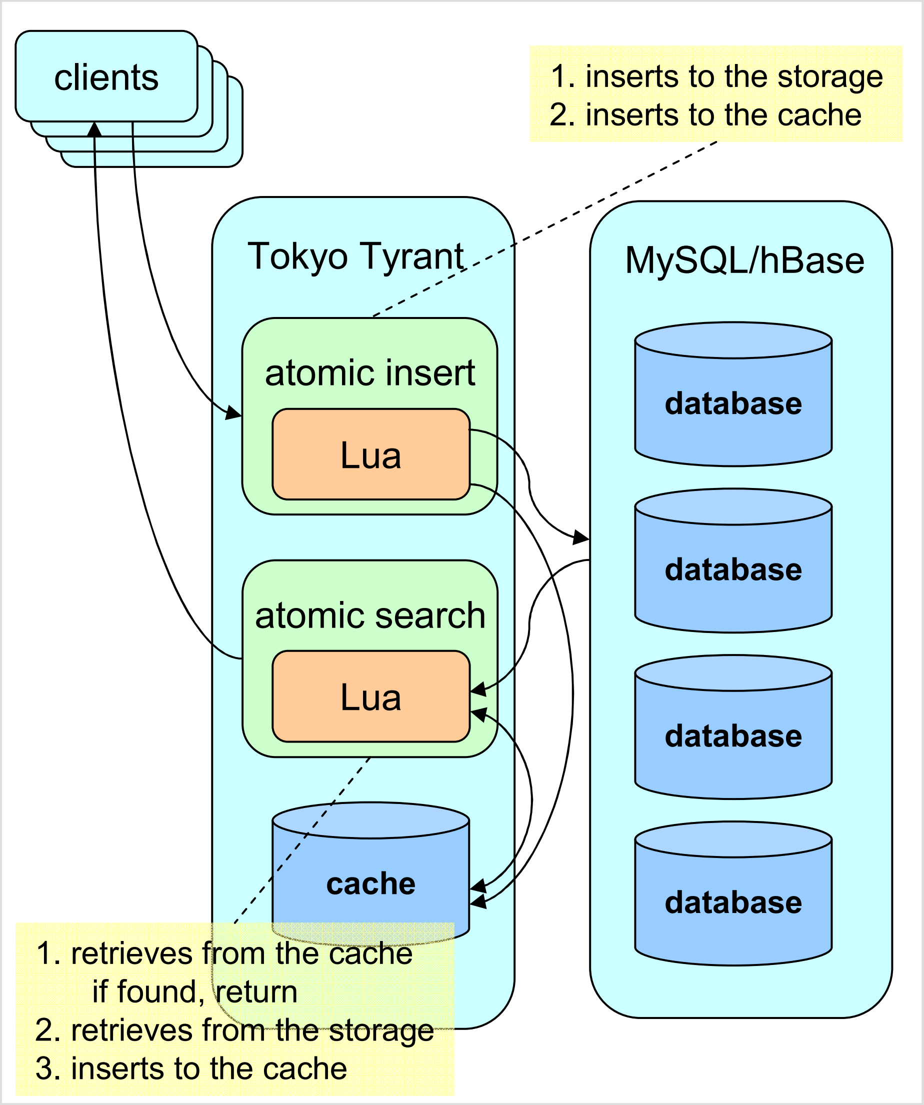
case: Timestamp DB at mixi.jp

- 20 million records
  - each record size is 20 bytes
- more than 10,000 updates per sec.
  - keeps 10,000 connections
- dual master replication
  - each server is only one
- memcached compatible protocol
  - reuses existing Perl clients



case: Cache of Big Storages

- works as proxy
  - mediate insert/search
- Lua extension
  - atomic operation by record locking
  - uses LuaSocket to access the storage
- proper DB scheme
  - TCMDB (hash table): suitable for generic cache
  - TCNDB (splay tree): suitable for biased access
  - TCHDB (file): suitable for large records such as image
  - TCFDB (file): suitable for small and fixed-length records such as timestamp



1. inserts to the storage
2. inserts to the cache

1. retrieves from the cache
   if found, return
2. retrieves from the storage
3. inserts to the cache

Example Code

```c
#include <tcrdb.h>
#include <stdlib.h>
#include <stdbool.h>
#include <stdint.h>

int main(int argc, char **argv){

  TCRDB *rdb;
  int ecode;
  char *value;

  /* create the object */
  rdb = tcrdbnew();

  /* connect to the server */
  if(!tcrdbopen(rdb, "localhost", 1978)){
    ecode = tcrdbecode(rdb);
    fprintf(stderr, "open error: %s¥n", tcrdberrmsg(ecode));
  }

  /* store records */
  if(!tcrdbput2(rdb, "foo", "hop") ||
     !tcrdbput2(rdb, "bar", "step") ||
     !tcrdbput2(rdb, "baz", "jump")){
    ecode = tcrdbecode(rdb);
    fprintf(stderr, "put error: %s¥n", tcrdberrmsg(ecode));
  }

  /* retrieve records */
  value = tcrdbget2(rdb, "foo");
  if(value){
    printf("%s¥n", value);
    free(value);
  } else {
    ecode = tcrdbecode(rdb);
    fprintf(stderr, "get error: %s¥n", tcrdberrmsg(ecode));
  }
```

```c
  /* close the connection */
  if(!tcrdbclose(rdb)){
    ecode = tcrdbecode(rdb);
    fprintf(stderr, "close error: %s¥n", tcrdberrmsg(ecode));
  }

  /* delete the object */
  tcrdbdel(rdb);

  return 0;
}
```

Tokyo Dystopia

- full-text search engine -

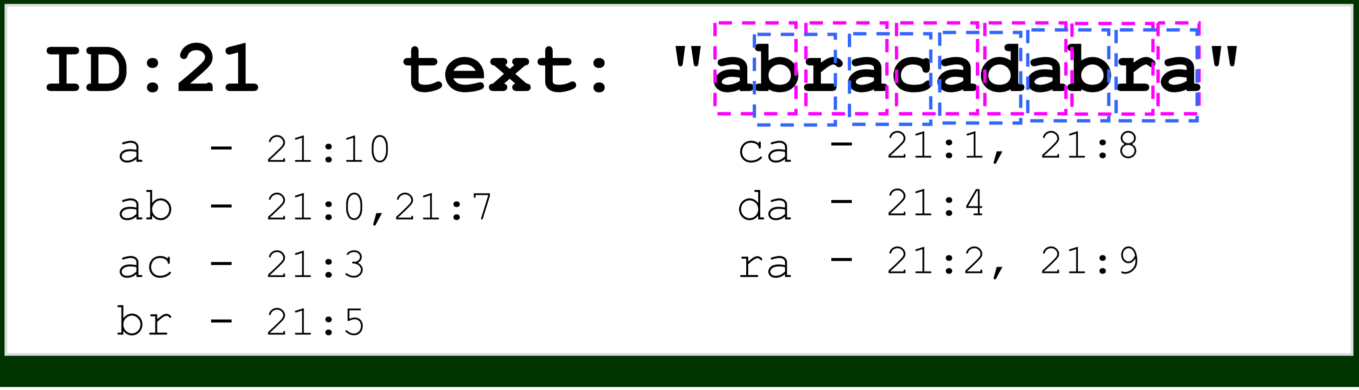
Features

- full-text search engine
  - manages databases of Tokyo Cabinet as an inverted index
- combines two tokenizers
  - character N-gram (bi-gram) method
    - perfect recall ratio
  - simple word by outer language processor
    - high accuracy and high performance
- high performance/scalability
  - handles more than 10 million documents
  - searches in milliseconds

- optimized to professional use
  - layered architecture of APIs
  - no embedded scoring system
    - to combine outer scoring system
  - no text filter, no crawler, no language processor
- convenient utilities
  - multilingualism with Unicode
  - set operations
  - phrase matching, prefix matching, suffix matching, and token matching
  - command line utilities

Inverted Index

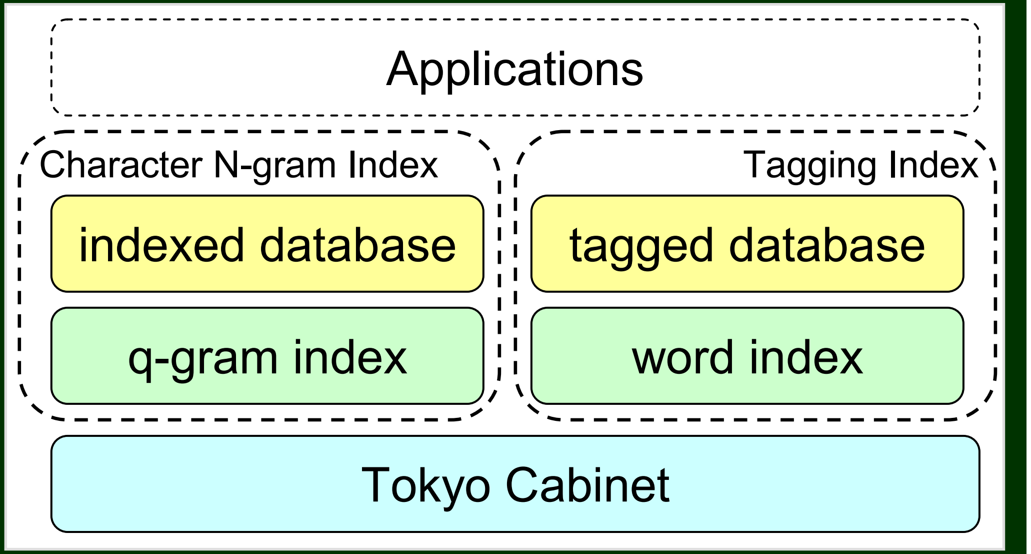
- stands on key/value database
  - key = token
    - N-gram or simple word
  - value = occurrence data (posting list)
    - list of pairs of document number and offset in the document
- uses B+ tree database
  - reduces write operations into the disk device
  - enables common prefix search for tokens
  - delta encoding and deflate compression



```
ID:21    text: "abracadabra"
   a  - 21:10              ca - 21:1, 21:8
   ab - 21:0,21:7          da - 21:4
   ac - 21:3               ra - 21:2, 21:9
   br - 21:5
```

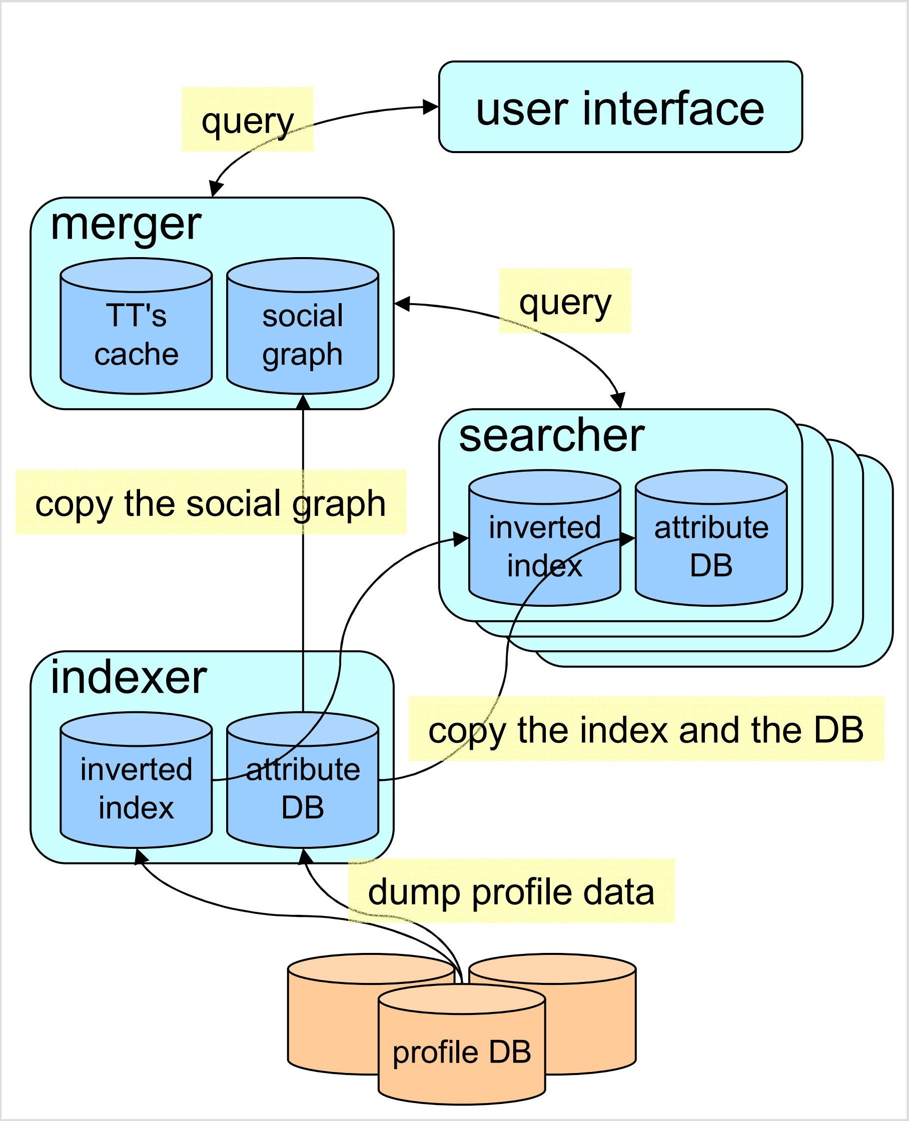
Layered Architecture

- **character N-gram index**
  - "q-gram index" (only index), and "indexed database"
  - uses embedded tokenizer
- **word index**
  - "word index" (only index), and "tagged index"
  - uses outer tokenizer



case: friend search at mixi.jp

- 20 million records
  - each record size is 1K bytes
  - name and self introduction
- more than 100 qps
- attribute narrowing
  - gender, address, birthday
  - multiple sort orders
- distributed processing
  - more than 10 servers
  - indexer, searchers, merger
- ranking by social graph
  - the merger scores the result by following the friend links



Example Code

```c
#include <dystopia.h>
#include <stdlib.h>
#include <stdbool.h>
#include <stdint.h>

int main(int argc, char **argv){
  TCIDB *idb;
  int ecode, rnum, i;
  uint64_t *result;
  char *text;

  /* create the object */
  idb = tcidbnew();

  /* open the database */
  if(!tcidbopen(idb, "casket", IDBOWRITER | IDBOCREAT)){
    ecode = tcidbecode(idb);
    fprintf(stderr, "open error: %s¥n", tcidberrmsg(ecode));
  }

  /* store records */
  if(!tcidbput(idb, 1, "George Washington") ||
     !tcidbput(idb, 2, "John Adams") ||
     !tcidbput(idb, 3, "Thomas Jefferson")){
    ecode = tcidbecode(idb);
    fprintf(stderr, "put error: %s¥n", tcidberrmsg(ecode));
  }
```

```c
  /* search records */
  result = tcidbsearch2(idb, "john || thomas", &rnum);
  if(result){
    for(i = 0; i < rnum; i++){
      text = tcidbget(idb, result[i]);
      if(text){
        printf("%d¥t%s¥n", (int)result[i], text);
        free(text);
      }
    }
    free(result);
  } else {
    ecode = tcidbecode(idb);
    fprintf(stderr, "search error: %s¥n", tcidberrmsg(ecode));
  }

  /* close the database */
  if(!tcidbclose(idb)){
    ecode = tcidbecode(idb);
    fprintf(stderr, "close error: %s¥n", tcidberrmsg(ecode));
  }

  /* delete the object */
  tcidbdel(idb);

  return 0;
}
```

innovating more and yet more...

http://tokyocabinet.sourceforge.net/

東京 ↖

キャビネット 8192 PiB