C++ - external libraries and OS interfaces

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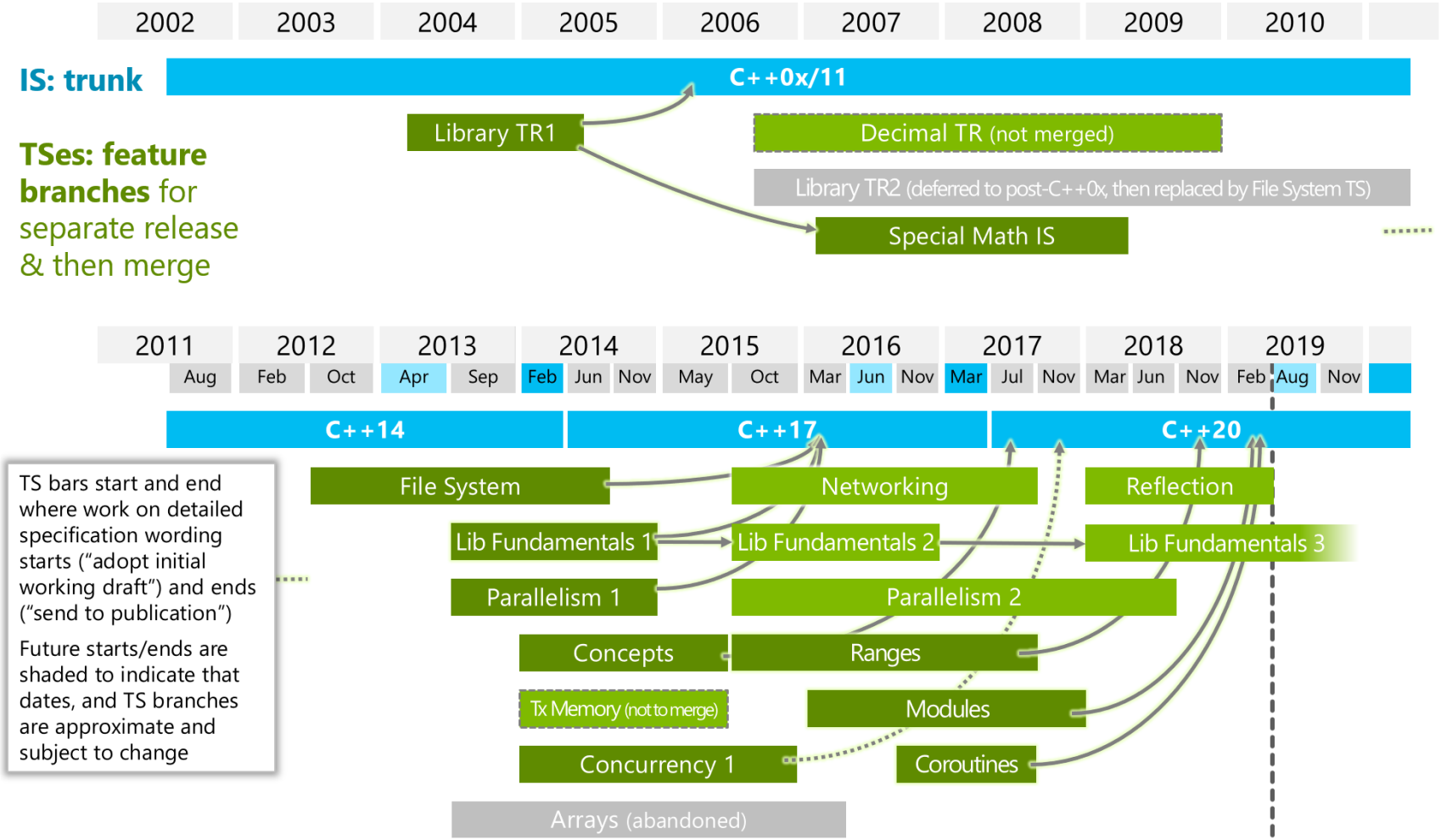
ISO C++ status


2002
2003
2004
2005
2006
2007
2008
2009
2010
IS: trunk
C++0x/11
Library TR1
Decimal TR (not merged)
TSes: feature branches for separate release & then merge
Library TR2 (deferred to post-C++0x, then replaced by File System TS)
Special Math IS
2011
2012
2013
2014
2015
2016
2017
2018
2019
Aug
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May
Oct
Mar
Jun
Nov
Mar
Jul
Nov
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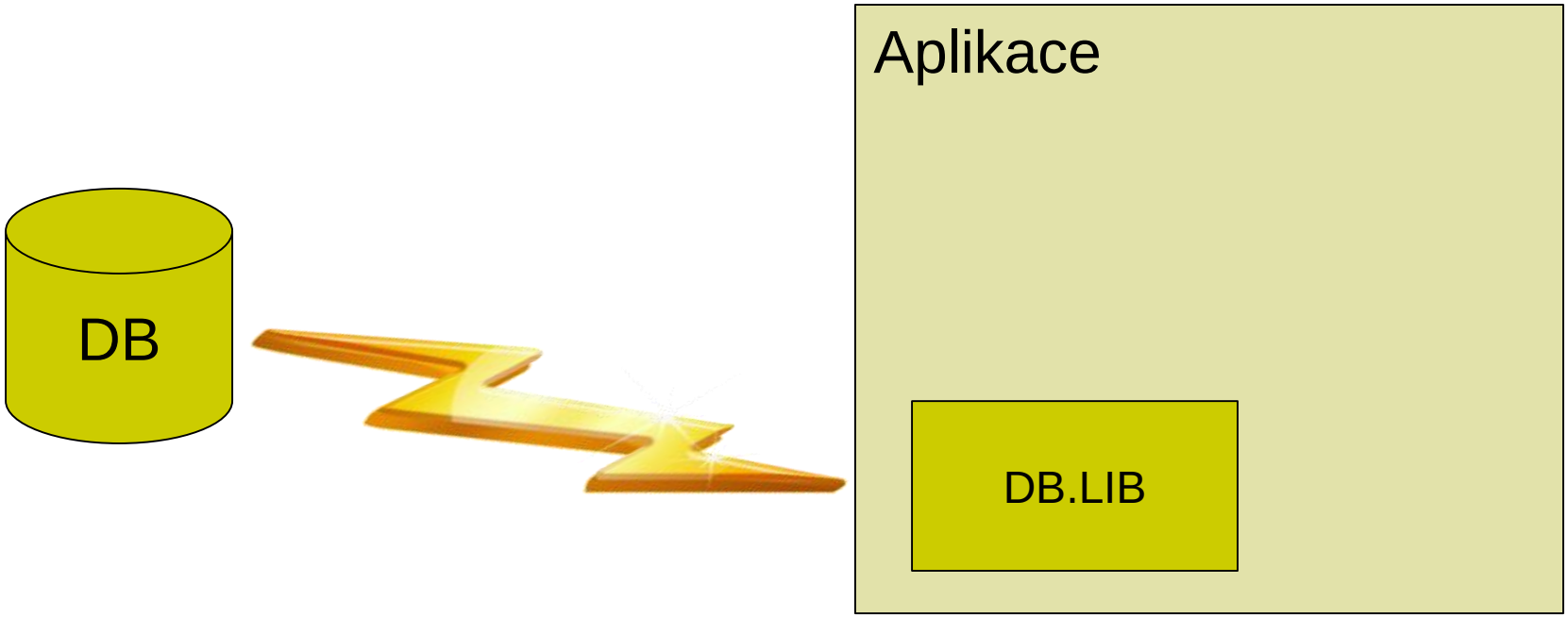
Aug
Nov
C++14
C++17
C++20
File System
Networking
Reflection
Lib Fundamentals 1
Lib Fundamentals 2
Lib Fundamentals 3
Parallelism 1
Parallelism 2
Concepts
Ranges
Tx Memory (not to merge)
Modules
Concurrency 1
Coroutines
Arrays (abandoned)
TS bars start and end where work on detailed specification wording starts ("adopt initial working draft") and ends ("send to publication")
Future starts/ends are shaded to indicate that dates, and TS branches are approximate and subject to change

Database

- Client connection



Database – native client

- Oracle
  - OCI
- MS Server
  - ODBC, OLE DB
- Sybase
  - Open client
- PostgreSQL
  - Proprietary
- MySQL
  - Proprietary

Database – interface selection

- Native client
  - Faster
  - Specific features available
  - Not portable (sometimes)
  - Bound to specific DB
- General client (ODBC, OLE DB)
  - Implemented using native clients
  - Slower due to added layer
  - Specific features not accessible
  - Unbound to specific DB?

Database – API

- ISO 9075:2008
  - Almost all interfaces conform
    - Excluding MySQL
  - Defines a program entities hierarchy
  - Defines an interface for manipulating with program entities

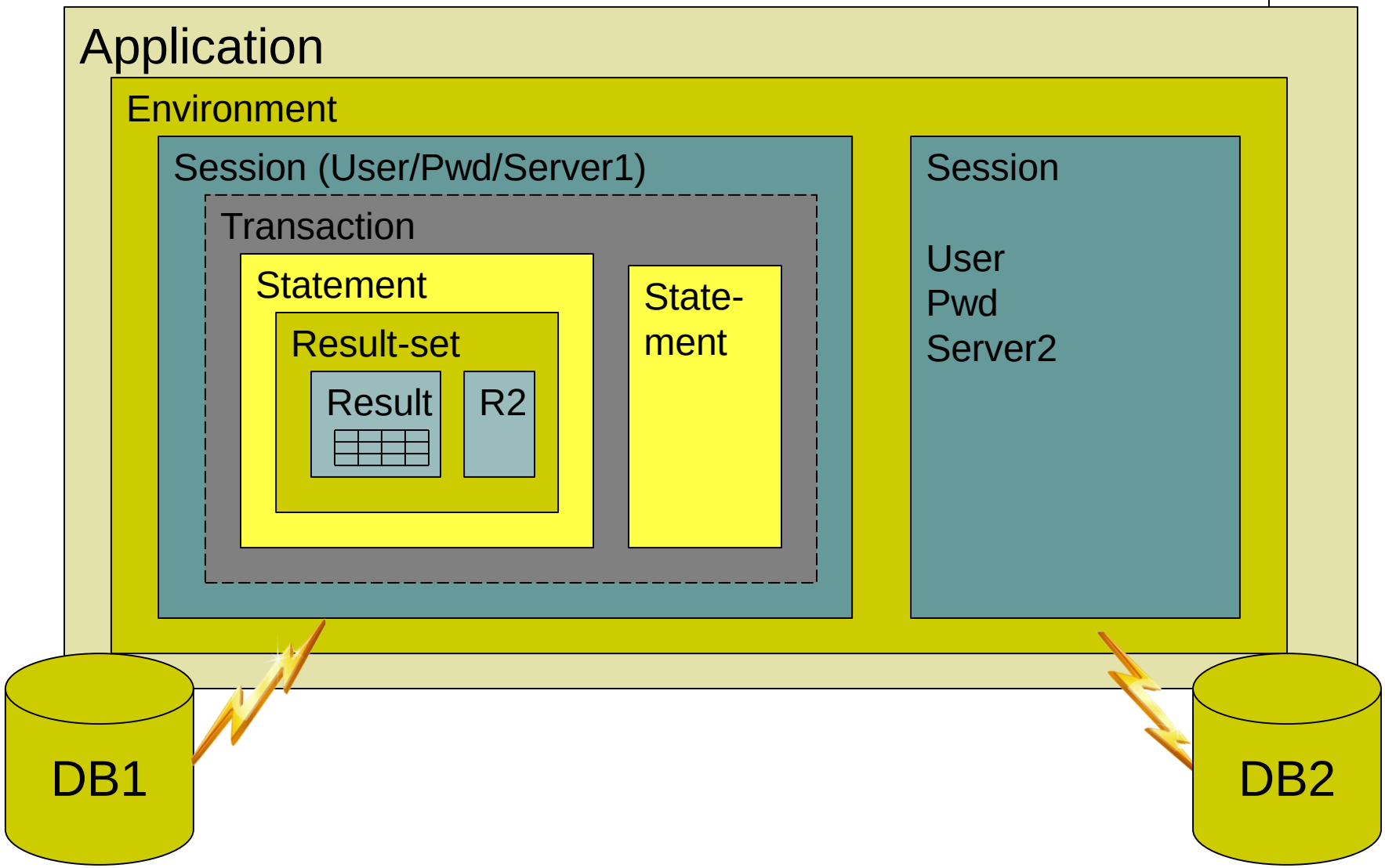
Database – program entities

- Environment
  - Global setting for client library in an application
  - Defines memory-management
- Session
  - Connection to one server
  - Properties session, user
  - Derived from the environment
- Statement
  - State space for one query
  - Prepared statement
  - Parameter binding
    - Static/dynamic, input/output
  - Derived from the session

Database – program entities

- Result-set
  - Container of results
  - Derived from the statement
- Result
  - Query result
  - Data binding
    - Static/dynamic
  - Derived from the result-set
- Transaction
  - Derived from the session

Database – program entities



Database – example

```
environment e;
CreateEnvironment(e);
session ses;
CreateSession(ses, e);
ConnectSession(ses, “user”,
    “pwd”, “srv”);
transaction t;
CreateTransaction(t, ses);
BeginTransaction(t);
statement stm;
CreateStatement(stm, ses);
int i, j;
BindParameter(stm, “q”, i, IN,
    C_INT, SQL_DEC);
result_set rs =
    ExecuteStatement(stm, “select
    * from t where c=:q”);
result r = rs.first();
BindColumn(r, 1, j, C_INT,
    SQL_DEC);
while(Fetch(r)) { }
DestroyResult(r);DestroyRS(rs);
CommitTransaction(t);
DestroyStatement(stm);
DestroyTransaction(t);
CloseSession(ses);
DestroySession(ses);
DestroyEnvironment(e);
```

Database – C++

- Something like SQLpp
  - Dead project

```
auto x = select(p.id, p.name, f.id.as(id2))
        .from(p, f)
        .where(p.name=any(select(f.name).from(f)))
        .group_by(f.name)
        .order_by(p.name.asc());
for(const auto & row : x)
{ int id = row.id; string name = row.name; }
```

Network

- C++23??
- BSD sockets
  - Winsock 2
- Socket
  - Abstract endpoint for network communication
  - Bind to different protocols
    - IPv4, IPv6
  - Bind to different kind of communication
    - Stream, datagram, raw
  - Bind to transportation protocol
    - TCP, UDP

Network – TCP client

```
SOCKET sock = socket(INET, STREAM, TCP);
struct sockaddr_in soain;
soain.sin_family = INET;
getaddrinfo(“www.nic.cz”, SRV_PORT, 0, &soain.sin_addr);
connect(sock, soain);
send(sock, buf, len);
recv(sock, buf, len);
shutdown(sock);
close(sock);
```

Network – TCP server

```
SOCKET listensock = socket(INET, STREAM, TCP);
struct sockaddr_in soain;
soain.sin_family = INET; soain.sin_port = SRV_PORT; soian.sin_addr
    = ANY;
bind(listensock, soain);
listen(listensock, queuedepth);
for(;;) {
    SOCKET sock = accept(listensock);              // blocks
    recv(sock, buf, len);   send(sock, buf, len);
    shutdown(sock);
    close(sock);
}
shutdown(listensock);
close(listensock);
```

Network – UDP client

```
SOCKET sock = socket(INET, DGRAM, UDP);
struct sockaddr_in soain;
soain.sin_family = INET;
getaddrinfo(“www.nic.cz”, SRV_PORT, 0, &soain.sin_addr);
sendto(sock, buf, len, &soain);
recvfrom(sock, buf, len, &soain);
close(sock);
```

Network – UDP server

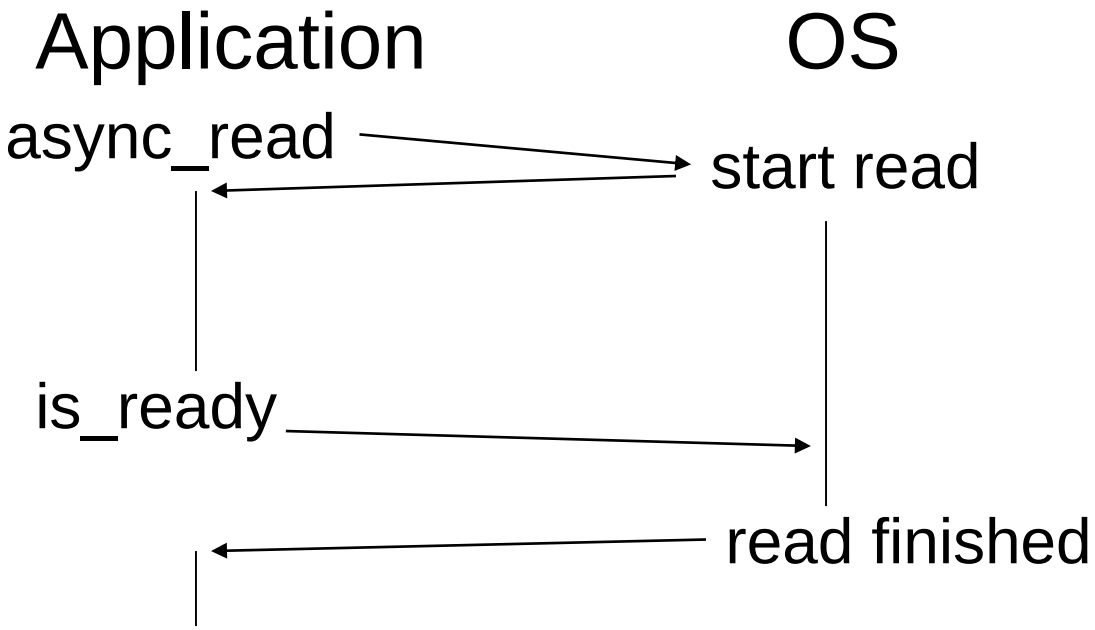
```
SOCKET sock = socket(INET, STREAM, TCP);
struct sockaddr_in soain;
soain.sin_family = INET; soain.sin_port = SRV_PORT; soian.sin_addr
    = ANY;
bind(sock, soain);
for(;;) {
    struct sockaddr_in soain_cli;
    int len = recvfrom(sock, buf, maxlen, &soain_cli);
    sendto(sock, buf, len, &soain_cli);
}
close(sock);
```

Network – remaining functions

- select
  - Wait for finished operations on sockets
- getaddrinfo
  - General translation from node name to a binary representation
- getnameinfo
  - General translation from binary representation to a node name and service name
- htons, htonl, ntohs, ntohl
  - Translation from host byte-order to network byte-order and vice versa

Asynchronous I/O

- Execute a file operation and continue in a work
  - A new entity created, which can be questioned for operation status or the application can wait for it
- What about coroutines?



Asynchronous I/O – demo

Windows

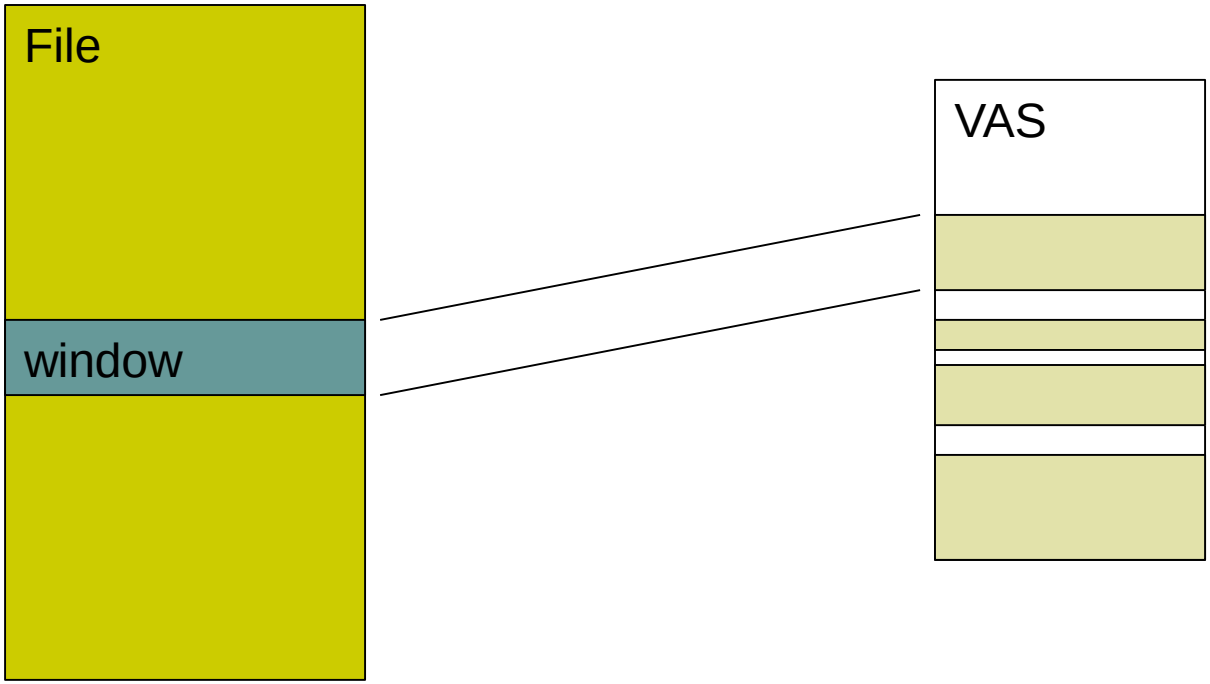
```
HANDLE f = CreateFile("f.txt",
    FILE_READ_DATA,
    FILE_SHARE_READ, 0,
    OPEN_EXISTING,
    FILE_FLAG_RANDOM_ACCESS |
    FILE_FLAG_OVERLAPPED, 0);
OVERLAPPED o;
memset(&o, 0, sizeof(OVERLAPPED));
o.hEvent = CreateEvent(0, TRUE, FALSE,
    0);
o.Offset = offs;
ReadFile(f, buf, sz, &rsz, &o);

WaitForSingleObject(o.hEvent, INFINITE);
CloseHandle(o.hEvent);
CloseHandle(f);
```

AIO

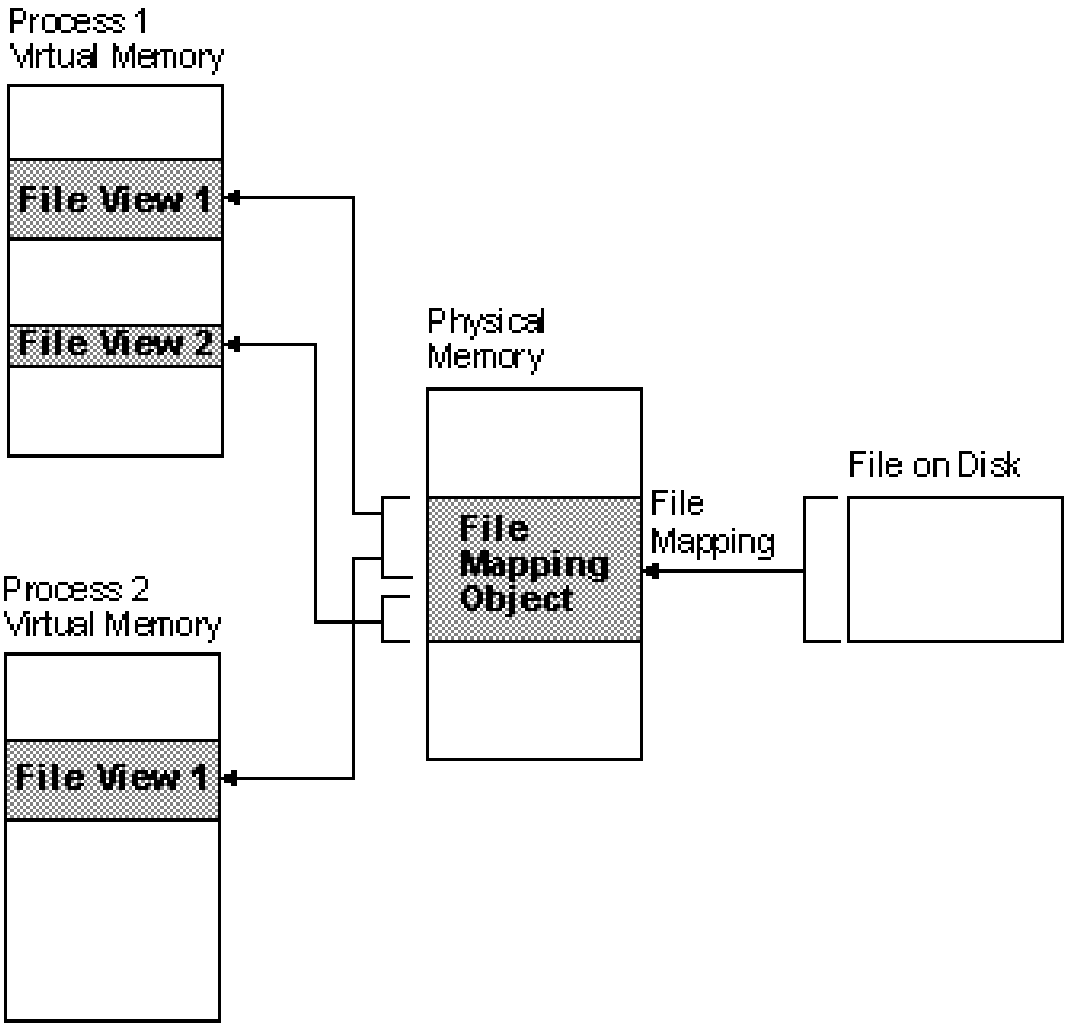
```
int f = open("f.txt", O_RDONLY |
    O_LARGEFILE, rights);
aiocb a;
memset(&a, 0, sizeof(aiocb));
aiocb. aio_fildes = f;
aiocb. aio_offset = offs;
aiocb. aio_nbytes = sz;
aiocb. aio_buf = buf;
aiocb. aio_sigevent.sigev_notify =
    SIGEV_NONE;
aio_read(&a);

aio_suspend(&a, 1, 0);
rsz = aio_return(&a);
close(f);
```

Memory mapped files

- Mapping, unmapping files
  - A file must be already opened
- Create, destroy window



Memory mapped files – Windows



Memory mapped files – demo

Windows

```
HANDLE f = CreateFile(“f.txt”,
    FILE_READ_DATA,
    FILE_SHARE_READ, 0,
    OPEN_EXISTING,
    FILE_FLAG_RANDOM_ACCESS, 0);
HANDLE m = CreateFileMapping(f, 0,
    PAGE_READONLY, 0, sz, 0);
void *p = MapViewOfFileEx(m,
    FILE_MAP_READ, 0, offs, sz, hinta);

UnmapViewOfFile(p);
CloseHandle(m);
CloseHandle(f);
```

POSIX

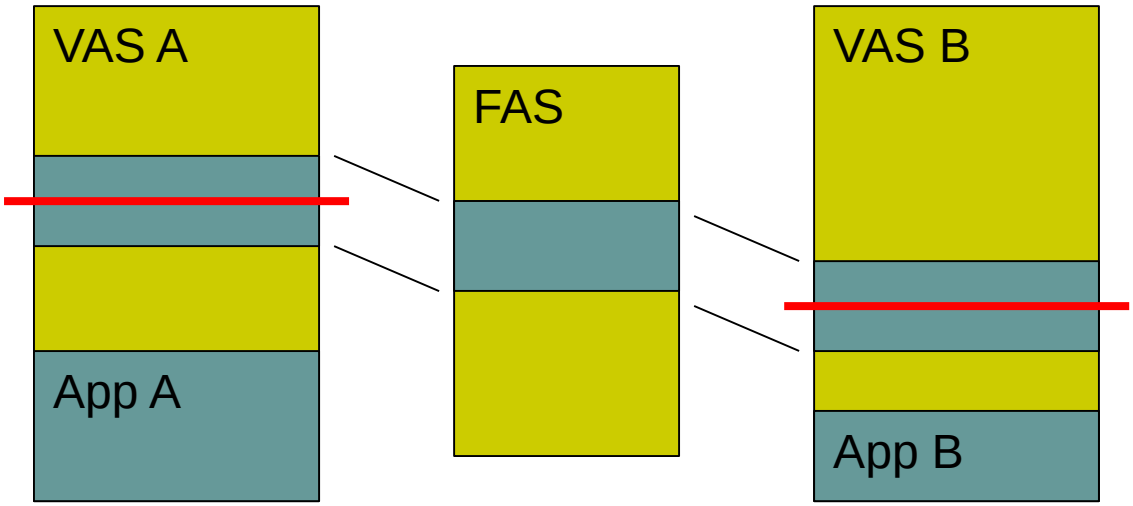
```
int f = open(“f.txt”, O_RDONLY |
    O_LARGEFILE, rights);
void *p = mmap(hinta, sz, PROT_READ,
    MAP_SHARED, f, offs);

munmap(p, sz);
close(f);
```

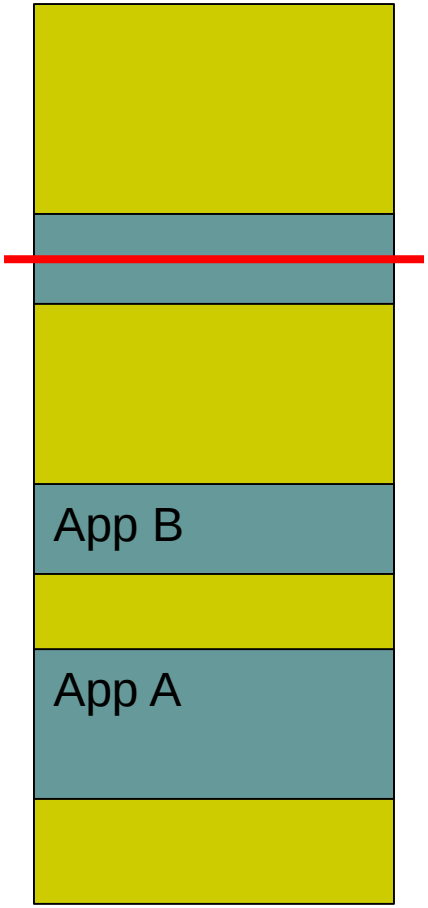
Filesystem

- Open, close directory
  - Some OS with name filtering
- Reading directory
  - Getting name, attributes, size, rights, …
- Create, remove directory
- Already in C++17

Shared memory

- Sharing memory among different processes
- Usually identified by a name
- Page granularity
- MASOS, SASOS
  - Offsets





Shared memory – demo SASOS

Windows client

```
HANDLE shm = OpenFileMapping(
    FILE_MAP_WRITE|FILE_MAP_READ,
    FALSE, “mymemory”);
void *p = MapViewOfFileEx(shm,
    FILE_MAP_READ, 0, 0, sz, hinta);
struct s { int n; int *ptr; };
for(int i=0;i<static_cast<s*>(p)->n;++i)
  cout << static_cast<s*>(p)->ptr[i];
UnmapViewOfFile(p);
CloseHandle(shm);
```

Windows server

```
HANDLE shm = CreateFileMapping
    (INVALID_HANDLE_VALUE, 0,
    PAGE_READWRITE, 0, sz,
    “mymemory”);
void *p = MapViewOfFileEx(shm,
    FILE_MAP_WRITE, 0, 0, sz, hinta);
struct s { int n; int *ptr; };
static_cast<s*>(p)->n = N;
static_cast<s*>(p)->ptr =
    static_cast<char*>(p)+sizeof(s);
for(int i=0;i<N;++i)
  static_cast<s*>(p)->ptr[i] = i;
UnmapViewOfFile(p);
CloseHandle(shm);
```

Shared memory – demo MASOS

Windows client

```
HANDLE shm = OpenFileMapping(
    FILE_MAP_WRITE|FILE_MAP_READ,
    FALSE, “mymemory”);
void *p = MapViewOfFileEx(shm,
    FILE_MAP_READ, 0, 0, sz, hinta);
struct s { int n; size_t offs; };
for(int i=0;i<static_cast<s*>(p)->n;++i)
  cout <<
    static_cast<int*>(static_cast<char*>(p)
    +static_cast<s*>(p)->offs)[i];
UnmapViewOfFile(p);
CloseHandle(shm);
```

Windows server

```
HANDLE shm = CreateFileMapping
    (INVALID_HANDLE_VALUE, 0,
    PAGE_READWRITE, 0, sz,
    “mymemory”);
void *p = MapViewOfFileEx(shm,
    FILE_MAP_WRITE, 0, 0, sz, hinta);
struct s { int n; size_t offs; };
static_cast<s*>(p)->n = N;
static_cast<s*>(p)->offs = sizeof(s);
for(int i=0;i<N;++i)
  static_cast<int*>(static_cast<char*>(p)
    +static_cast<s*>(p)->offs)[i] = i;
UnmapViewOfFile(p);
CloseHandle(shm);
```

Shared memory – demo

POSIX client

```
int shm = shm_open(“mymemory”,
    O_RDWR, rights);
void *p = mmap(hinta, sz, PROT_READ,
    MAP_SHARED, shm, 0);
struct s { int n; int *ptr; };
for(int i=0;i<static_cast<s*>(p)->n;++i)
  cout << static_cast<s*>(p)->ptr[i];
munmap(p, sz);
close(shm);
shm_unlink(“mymemory”);
```

POSIX server

```
int shm = shm_open(“mymemory”,
    O_RDWR|O_CREAT|O_EXCL,
    rights);
void *p = mmap(hinta, sz,
    PROT_READ|PROT_WRITE,
    MAP_SHARED, shm, 0);
struct s { int n; int *ptr; };
static_cast<s*>(p)->n = N;
static_cast<s*>(p)->ptr =
    static_cast<char*>(p)+sizeof(s);
for(int i=0;i<N;++i)
  static_cast<s*>(p)->ptr[i] = i;
munmap(p, sz);
close(shm);
shm_unlink(“mymemory”);
```

POSIX

- Portable Operating System Interface [for Unix]
  - Existing native implementation for Win NT
  - Single UNIX Specification
  - IEEE standard
  - API
  - Shell
  - Utility

POSIX – versions

- POSIX.1
  - API (includes ANSI C)
  - 1988
- POSIX.1b
  - Real-time extension
  - 1993
- POSIX.1c
  - Thread extension
  - 1995
- POSIX.2
  - Shell and utility
  - 1992
- POSIX:2001
  - API, shell, utility
- POSIX:2004
  - Update and corrigendum
- POSIX:2008
  - API, shell, utility

POSIX – compatibility

- Full
  - AIX, HP-UX, Solaris, Mac OS X, …
- Partial
  - FreeBSD, GNU/Linux, OpenSolaris, …
- Windows
  - Cygwin – partial compatibility
  - MS Windows Services for UNIX 3.5 – full compatibility

Boost

- Portable C++ library
  - Review process
  - Source and testing ground for ISO
    - Tightly coupled with ISO comittee
  - Large set of supported OSs and compilers
  - Very good library, sometimes too abstract

Boost – containers

- Array
  - Constant size array
  - ISO C++ TR1/C++ 11
- Bimap
  - Two-sided map
- Circular buffer
- Graph
- Variant
  - Secure union
  - ISO C++17

Boost – parallel programming support

- Interprocess
  - Shared memory
  - Memory mapped files
  - Mutexes
    - ISO C++ 11
- MPI
- Thread
  - ISO C++ 11

Boost – I/O

- Asio
  - Asynchronous I/O, executors, networking, …
  - Parts maybe in C++20?
- Format
  - Enhanced formatting like printf
- Program options
  - Command line parameters
- Serialization
  - Data serialization for saving or marshalling

Boost – mathematic and numeric

- Intervals
- Multi-array
- Random
  - ISO C++ TR1/C++ 11

Boost – generic programming and metaprogramming

- GIL
  - Generic Image Library
- Static assert
  - ISO C++ 11
- Type traits
  - ISO C++ TR1/C++ 11
- MPL
  - General framework for compile-time algorithms, sequences, and metafunctions

Boost – strings

- Lexical cast
- Regex
  - ISO C++ TR1/C++ 11
- Spirit
  - LL parser
- String algo
- Tokenizer
  - Splitting a string to tokens

Boost – unsorted

- Shared ptr
  - ISO C++ TR1/C++ 11
- Date time
  - ISO C++ 11
- Filesystem
  - Paths, directory, files
  - ISO C++17