Inside PostgreSQL Shared Memory

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POSTGRESQL is an open-source, full-featured relational database. This presentation gives an overview of the shared memory structures used by Postgres.

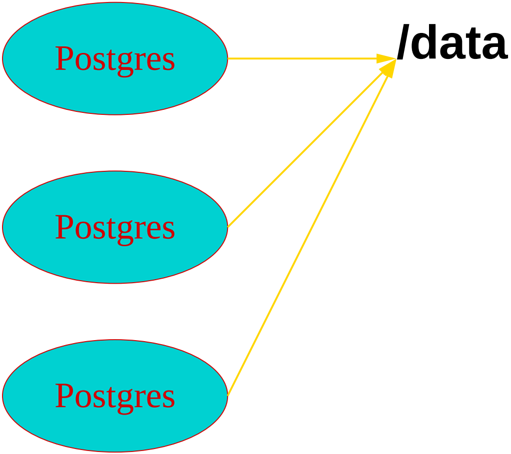
 http://momjian.us/presentations

Last updated: September, 2015

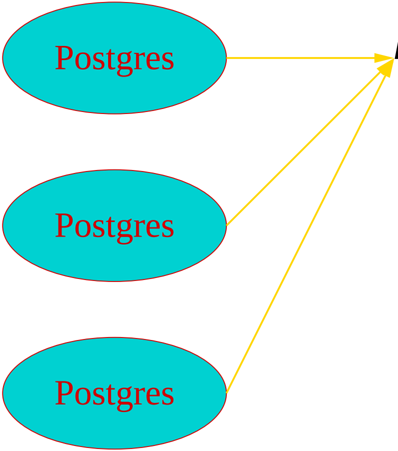
Outline

1. File storage format
2. Shared memory creation
3. Shared buffers
4. Row value access
5. Locking
6. Other structures

File System /data



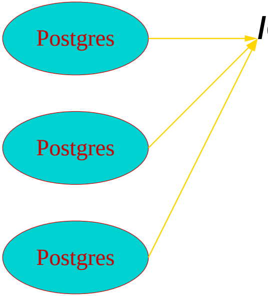
File System /data/base



/data **/base**

/global
/pg_clog
/pg_multixact
/pg_subtrans
/pg_tblspc
/pg_twophase
/pg_xlog

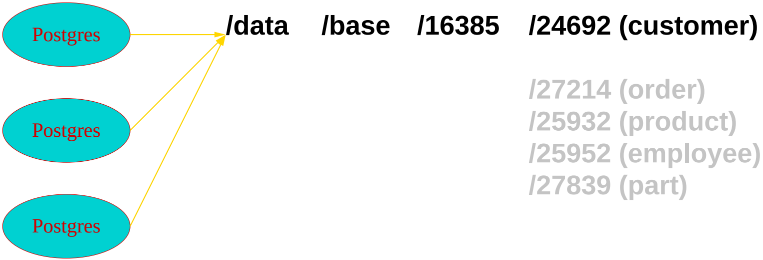
File System /data/base/db



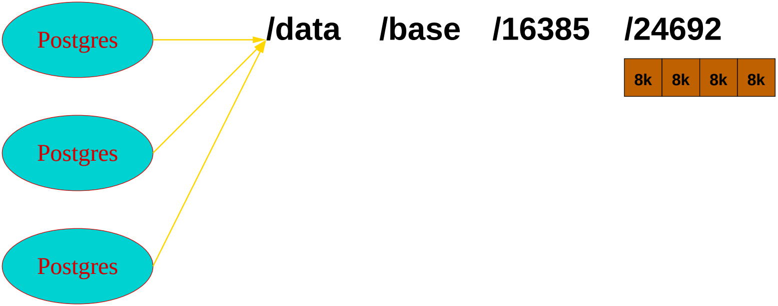
/data /base /16385 (production)

/1 (template1)
/16821 (test)
/17982 (devel)
/21452 (marketing)

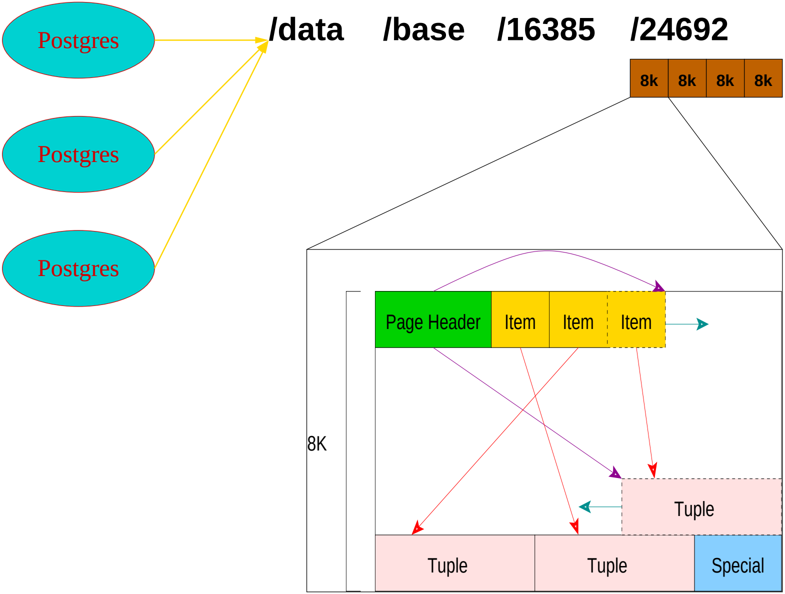
File System /data/base/db/table



File System Data Pages

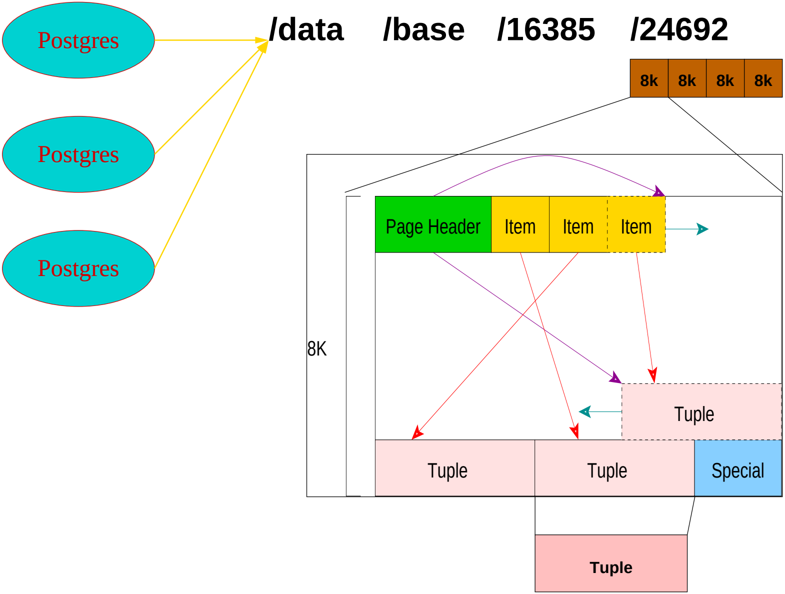


Data Pages

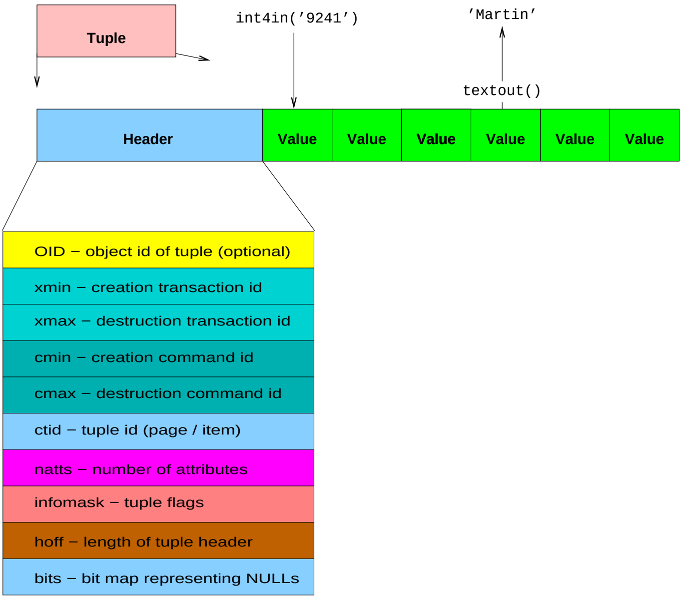


Postgres
Postgres
Postgres
/data /base /16385 /24692
8k
8k
8k
8k
8K
Page Header
Item
Item
Item
Tuple
Tuple
Tuple
Special

File System Block Tuple



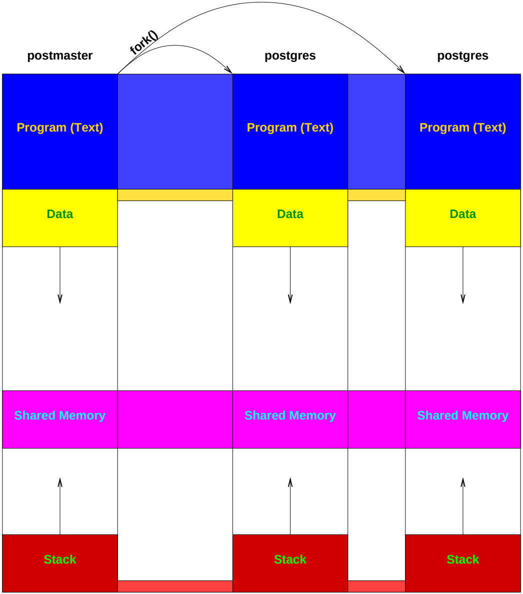
File System Tuple



Tuple Header C Structures

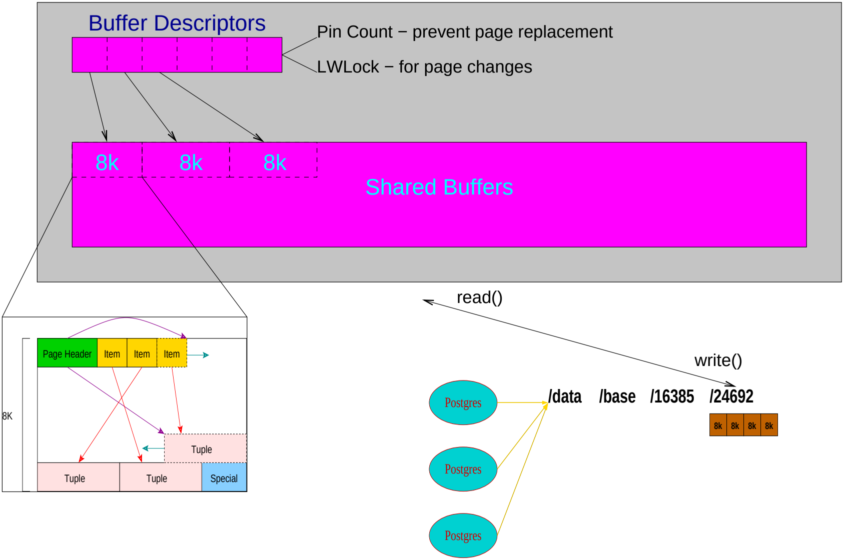
```
typedef struct HeapTupleFields
{
    TransactionId t_xmin;       /* inserting xact ID */
    TransactionId t_xmax;       /* deleting or locking xact ID */

    union
    {
        CommandId   t_cid;      /* inserting or deleting command ID, or both */
        TransactionId t_xvac;   /* VACUUM FULL xact ID */
    }           t_field3;
} HeapTupleFields;

typedef struct HeapTupleHeaderData
{
    union
    {
        HeapTupleFields t_heap;
        DatumTupleFields t_datum;
    }           t_choice;

    ItemPointerData t_ctid;     /* current TID of this or newer tuple */

    /* Fields below here must match MinimalTupleData! */

    uint16      t_infomask2;    /* number of attributes + various flags */

    uint16      t_infomask;     /* various flag bits, see below */

    uint8       t_hoff;         /* sizeof header incl. bitmap, padding */

    /* ^ - 23 bytes - ^ */

    bits8       t_bits[1];      /* bitmap of NULLs -- VARIABLE LENGTH */

    /* MORE DATA FOLLOWS AT END OF STRUCT */
} HeapTupleHeaderData;
```

Shared Memory Creation

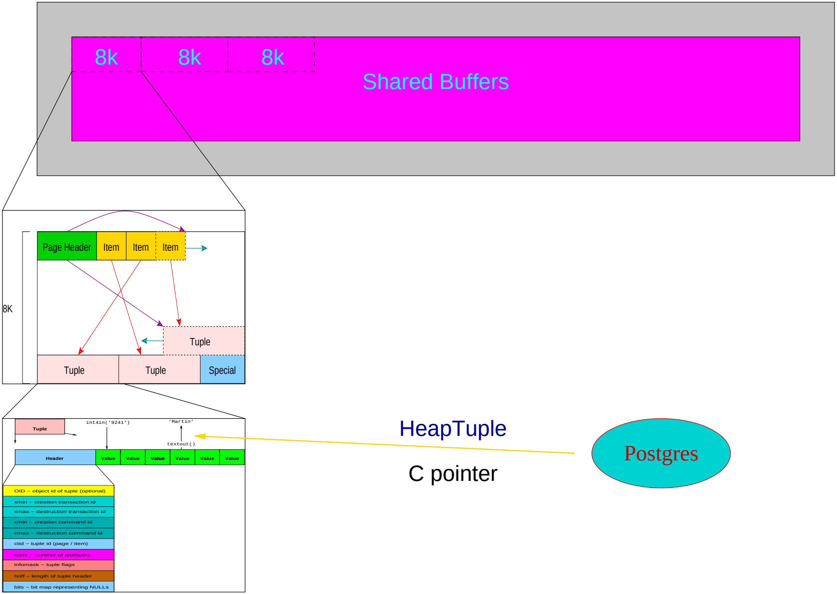


Shared Memory

Shared Buffers



HeapTuples



8k
8k
8k
Shared Buffers
8K
Page Header
Item
Item
Item
Tuple
Tuple
Tuple
Special
Tuple
int4in('9241')
'Martin'
textout()
Header
Value
Value
Value
Value
Value
Value
OID – object id of tuple (optional)
xmin – creation transaction id
xmax – destruction transaction id
cmin – creation command id
cmax – destruction command id
ctid – tuple id (page / item)
natts – number of attributes
infomask – tuple flags
hoff – length of tuple header
bits – bit map representing NULLs
HeapTuple
C pointer
Postgres

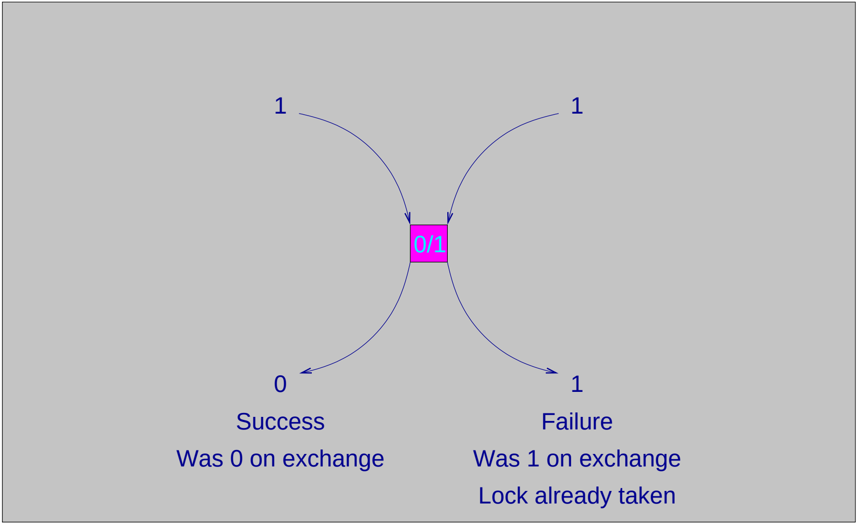
Finding A Tuple Value in C

```
Datum
nocachegetattr(HeapTuple tuple,
               int attnum,
               TupleDesc tupleDesc,
               bool *isnull)
{
    HeapTupleHeader tup = tuple->t_data;
    Form_pg_attribute *att = tupleDesc->attrs;

    {
        int         i;

        /*
         * Note - This loop is a little tricky.  For each non-null attribute,
         * we have to first account for alignment padding before the attr,
         * then advance over the attr based on its length.  Nulls have no
         * storage and no alignment padding either.  We can use/set
         * attcacheoff until we reach either a null or a var-width attribute.
         */
        off = 0;
        for (i = 0;; i++)       /* loop exit is at "break" */
        {
            if (HeapTupleHasNulls(tuple) && att_isnull(i, bp))
                continue;       /* this cannot be the target att */

            if (att[i]->attlen == -1)
                off = att_align_pointer(off, att[i]->attalign, -1,
                                        tp + off);
            else
                /* not varlena, so safe to use att_align_nominal */
                off = att_align_nominal(off, att[i]->attalign);

            if (i == attnum)
                break;

            off = att_addlength_pointer(off, att[i]->attlen, tp + off);
        }
    }

    return fetchatt(att[attnum], tp + off);
}
```

Value Access in C

```
#define fetch_att(T,attbyval,attlen) \
( \
    (attbyval) ? \
    ( \
        (attlen) == (int) sizeof(int32) ? \
            Int32GetDatum(*((int32 *)(T))) \
        : \
        ( \
            (attlen) == (int) sizeof(int16) ? \
                Int16GetDatum(*((int16 *)(T))) \
            : \
            ( \
                AssertMacro((attlen) == 1), \
                CharGetDatum(*((char *)(T))) \
            ) \
        ) \
    ) \
    : \
    PointerGetDatum((char *) (T)) \
)
```

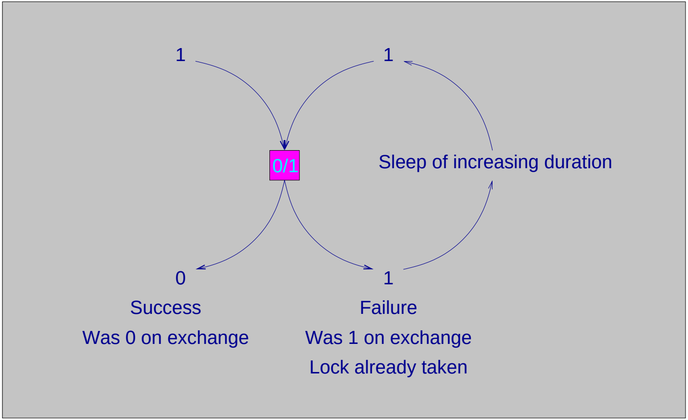
Test And Set Lock
Can Succeed Or Fail



Test And Set Lock
x86 Assembler

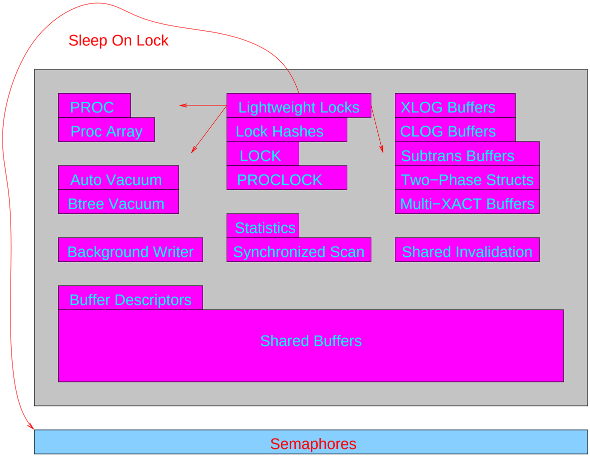
```
static __inline__ int
tas(volatile slock_t *lock)
{
    register slock_t _res = 1;

    /*
     * Use a non-locking test before asserting the bus lock.  Note that the
     * extra test appears to be a small loss on some x86 platforms and a small
     * win on others; it's by no means clear that we should keep it.
     */
    __asm__ __volatile__(
        "   cmpb    $0,%1   \n"
        "   jne     1f      \n"
        "   lock            \n"
        "   xchgb   %0,%1   \n"
        "1: \n"
:       "+q"(_res), "+m"(*lock)
:
:       "memory", "cc");
    return (int) _res;
}
```

Spin Lock
Always Succeeds



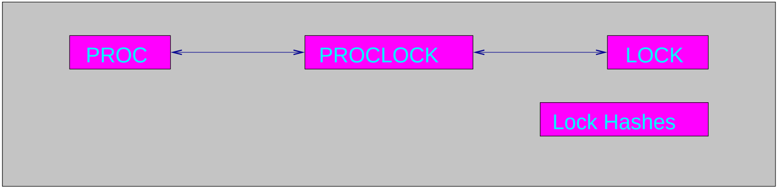
Spinlocks are designed for short-lived locking operations, like access to control structures. They are not be used to protect code that makes kernel calls or other heavy operations.

Light Weight Locks

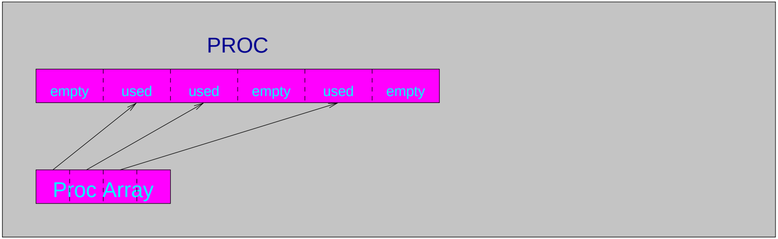


Light weight locks attempt to acquire the lock, and go to sleep on a semaphore if the lock request fails. Spinlocks control access to the light weight lock control structure.

Database Object Locks



Proc



Other Shared Memory Structures

Conclusion

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Pink Floyd: Wish You Were Here