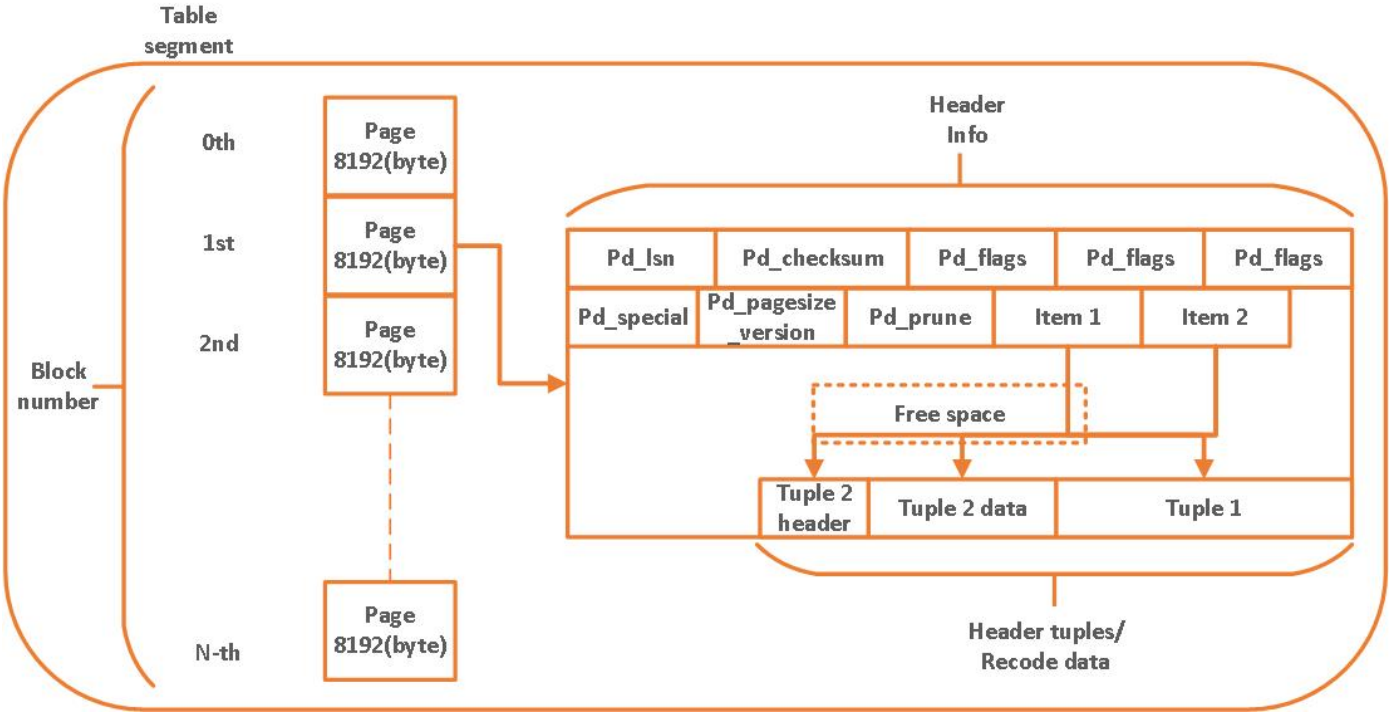
前言

对于从事PostgreSQL相关的，不管你是开发还是运维，肯定都或多或少听到过标志位这个东东，云里雾里，大概了解这个标志位可以加速事务的获取、标识某些状态信息等等，为了弥补这一块的知识空缺。

何为infomask

首先我们需要简单了解一下PostgreSQL的内部结构，数据块的结构如下 👇，默认8KB，最大32KB，在此不过多介绍，度娘一堆。

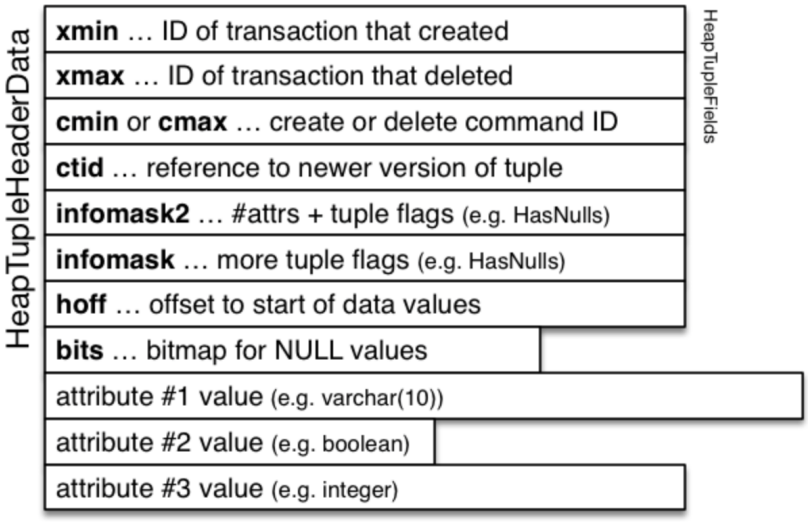


下面是Tuple的具体结构，Tuple头部是由23byte固定大小的前缀和可选的NullBitMap构成，当元组中存在空值时，会出现空值位图，每个字段占一位，远远大于Oracle的3字节，也比Mysql略大。所以在PostgreSQL里面，存储的额外开销要略大于Oracle，另外值得注意的是可能还会有字节对齐，在此表过不提。

我们关心的是infomask，more tuple flags，可以看到，是关于元组Tuple的一些标志位，用于标识元组的一些属性和状态。

PostgreSQL Tuples (cont)

Tuple structure:



在源码里面，infomask有如下这么多状态位，可以看到，就是通过比特位来标识某些属性，比如是否具有空属性、是否具有变长的属性

```
/*
 * information stored in t_infomask:
 */
#define HEAP_HASNULL            0x0001  /* has null attribute(s) */
#define HEAP_HASVARWIDTH        0x0002  /* has variable-width attribute(s) */
#define HEAP_HASEXTERNAL        0x0004  /* has external stored attribute(s) */
#define HEAP_HASOID_OLD         0x0008  /* has an object-id field */
#define HEAP_XMAX_KEYSHR_LOCK 0x0010  /* xmax is a key-shared locker */
#define HEAP_COMBOCID           0x0020  /* t_cid is a combo cid */
#define HEAP_XMAX_EXCL_LOCK     0x0040  /* xmax is exclusive locker */
#define HEAP_XMAX_LOCK_ONLY     0x0080  /* xmax, if valid, is only a locker */

 /* xmax is a shared locker */
#define HEAP_XMAX_SHR_LOCK  (HEAP_XMAX_EXCL_LOCK | HEAP_XMAX_KEYSHR_LOCK)

#define HEAP_LOCK_MASK  (HEAP_XMAX_SHR_LOCK | HEAP_XMAX_EXCL_LOCK | \
             HEAP_XMAX_KEYSHR_LOCK)
#define HEAP_XMIN_COMMITTED     0x0100  /* t_xmin committed */
#define HEAP_XMIN_INVALID       0x0200  /* t_xmin invalid/aborted */
#define HEAP_XMIN_FROZEN        (HEAP_XMIN_COMMITTED|HEAP_XMIN_INVALID)
#define HEAP_XMAX_COMMITTED     0x0400  /* t_xmax committed */
#define HEAP_XMAX_INVALID       0x0800  /* t_xmax invalid/aborted */
#define HEAP_XMAX_IS_MULTI      0x1000  /* t_xmax is a MultiXactId */
#define HEAP_UPDATED            0x2000  /* this is UPDATEd version of row */
#define HEAP_MOVED_OFF          0x4000  /* moved to another place by pre-9.0
                     * VACUUM FULL; kept for binary
                     * upgrade support */
```

```
#define HEAP_MOVED_IN     0x8000  /* moved from another place by pre-9.0
                     * VACUUM FULL; kept for binary
                     * upgrade support */
#define HEAP_MOVED (HEAP_MOVED_OFF | HEAP_MOVED_IN)

#define HEAP_XACT_MASK      0xFFF0  /* visibility-related bits */

/*
 * A tuple is only locked (i.e. not updated by its Xmax) if the
 * HEAP_XMAX_LOCK_ONLY bit is set; or, for pg_upgrade's sake, if the Xmax is
 * not a multi and the EXCL_LOCK bit is set.
 *
 * See also HeapTupleHeaderIsOnlyLocked, which also checks for a possible
 * aborted updater transaction.
 *
 * Beware of multiple evaluations of the argument.
 */


 /*
 * information stored in t_infomask2:
 */
#define HEAP_NATTS_MASK     0x07FF  /* 11 bits for number of attributes */
/* bits 0x1800 are available */
#define HEAP_KEYS_UPDATED   0x2000  /* tuple was updated and key cols
                     * modified, or tuple deleted */
#define HEAP_HOT_UPDATED    0x4000  /* tuple was HOT-updated */
#define HEAP_ONLY_TUPLE     0x8000  /* this is heap-only tuple */

#define HEAP2_XACT_MASK     0xE000  /* visibility-related bits */
```

这里分享一个实用函数，可以直接获取infomask和infomask2里面的标志位信息

```
create type infomask_bit_desc as (mask varbit, symbol text);

create or replace function infomask(msk int, which int) returns text
language plpgsql as $$
declare
        r infomask_bit_desc;
        str text = '';
        append_bar bool = false;
begin
        for r in select * from infomask_bits(which) loop
                if (msk::bit(16) & r.mask)::int <> 0 then
                        if append_bar then
                                str = str || '|';
                        end if;
                        append_bar = true;
                        str = str || r.symbol;
```

```
                end if;
        end loop;
        return str;
end;
$$ ;

create or replace function infomask_bits(which int)
returns setof infomask_bit_desc
language plpgsql as $$
begin
        if which = 1 then
                return query values
                (x'8000'::varbit, 'MOVED_IN'),
                (x'4000', 'MOVED_OFF'),
                (x'2000', 'UPDATED'),
                (x'1000', 'XMAX_IS_MULTI'),
                (x'0800', 'XMAX_INVALID'),
                (x'0400', 'XMAX_COMMITTED'),
                (x'0200', 'XMIN_INVALID'),
                (x'0100', 'XMIN_COMMITTED'),
                (x'0080', 'XMAX_LOCK_ONLY'),
                (x'0040', 'EXCL_LOCK'),
                (x'0020', 'COMBOCID'),
                (x'0010', 'XMAX_KEYSHR_LOCK'),
                (x'0008', 'HASOID'),
                (x'0004', 'HASEXTERNAL'),
                (x'0002', 'HASVARWIDTH'),
                (x'0001', 'HASNULL');
        elsif which = 2 then
                return query values
                (x'2000'::varbit, 'UPDATE_KEY_REVOKED'),
                (x'4000', 'HOT_UPDATED'),
                (x'8000', 'HEAP_ONLY_TUPLE');
        end if;
end;
$$;
```

下面让我们一个个来分析这些标志位!

HEAP_HASNULL & HASVARWIDTH

这个标志位很明显，就是用于判断是否具有空列，见如下样例，可以看到第一行因为是 text 变长列，所以置了HASVARWIDTH的标志位，第二行和第三行插入了null，所以置了HASNULL的标志位。

```
#define HEAP_HASNULL      0x0001  /* has null attribute(s) */
#define HEAP_HASVARWIDTH    0x0002  /* has variable-width attribute(s) */
```

```
postgres=# create table nullt1(id int,info text);
```

```
CREATE TABLE
postgres=# insert into nullt1 values(1,'xiongcc');
INSERT 0 1
postgres=# insert into nullt1 values(1,null);
INSERT 0 1
postgres=# insert into nullt1 values(null,null);
INSERT 0 1
postgres=# select lp, t_xmin, t_xmax, t_ctid,
       infomask(t_infomask, 1) as infomask,
       infomask(t_infomask2, 2) as infomask2
from heap_page_items(get_raw_page('nullt1', 0));
 lp | t_xmin   | t_xmax | t_ctid |          infomask          | infomask2
----+---------+--------+--------+---------------------------+-----------
  1 | 3643895 |      0 | (0,1)  | XMAX_INVALID|HASVARWIDTH |
  2 | 3643896 |      0 | (0,2)  | XMAX_INVALID|HASNULL     |
  3 | 3643897 |      0 | (0,3)  | XMAX_INVALID|HASNULL     |
(3 rows
```

HEAP_HASEXTERNAL

元组是否包含外部存储的字段

```
#define HEAP_HASEXTERNAL    0x0004  /* has external stored attribute(s) */
```

```
postgres=# create table blog(id int, title text, content text);
CREATE TABLE
postgres=# \d+ blog
                                    Table "public.blog"
 Column  |  Type   | Collation | Nullable | Default | Storage  | Stats target |
Description
---------+---------+-----------+----------+---------+----------+--------------+--------
-----
 id      | integer |           |          |         | plain    |              |
 title   | text    |           |          |         | extended |              |
 content | text    |           |          |         | extended |              |
Access method: heap
```

可以看到int类型默认策略为plain，而text为extended ，目前PostgreSQL支持的存储方式共有4种：

1. PLAIN： 避免压缩和行外存储。
2. EXTENDED： 先压缩，后行外存储。
3. EXTERNAL： 允许行外存储，但不许压缩。
4. MAIN： 允许压缩，尽量不使用行外存储。

那么，何时压缩数据？何时行外存储呢？

Tuple压缩：当Tuple大小超过大概2KB时，大概1/4个Block大小时，PostgreSQL会尝试基于LZ压缩算法进行压缩，另外在v14里面直接对表支持了LZ4压缩算法

```
postgres=# CREATE TABLE tab_compression (
     a text COMPRESSION pglz,
     b text COMPRESSION lz4);
CREATE TABLE
postgres=# \d+ tab_compression
                                    Table "public.tab_compression"
 Column | Type | Collation | Nullable | Default | Storage  | Compression | Stats target
| Description
--------+------+-----------+----------+---------+----------+-------------+-------------
-+-------------
 a      | text |           |          |         | extended | pglz        |
|
 b      | text |           |          |         | extended | lz4         |
|
Access method: heap
```

行外存储 (TOAST)：Toast属性的本意是The Oversized-Attribute Storage Technique，主要用来应对物理数据行超过数据块大小的场景，对于某个超长的属性单独存储，因为PostgreSQL不允许Tuple跨页存储，因此页的大小就是行大小的硬上限，当某行数据超过PostgreSQL页大小 (8K) 后，会将这个页放到系统命名空间pg_toast下的一个单独的表中，而在原表中存储一个TOAST pointer

```
typedef struct
{
    uint8       va_header;      /* Always 0x80 or 0x01 */
    uint8       va_tag;         /* Type of datum */
    char        va_data[FLEXIBLE_ARRAY_MEMBER]; /* Type-specific data */
} varattrib_1b_e;

typedef struct varatt_external
{
    int32       va_rawsize;     /* Original data size (includes header) */
    int32       va_extsize;     /* External saved size (doesn't) */
    Oid         va_valueid;     /* Unique ID of value within TOAST table */
    Oid         va_toastrelid;  /* RelID of TOAST table containing it */
}           varatt_external;
```

看一下blog表的Toast存储在哪里

```
postgres=# select relname,relfilenode,reltoastrelid from pg_class where relname='blog';
 relname | relfilenode | reltoastrelid
---------+-------------+---------------
 blog    |       49444 |         49447
(1 row)

postgres=# \d pg_toast.pg_toast_49444
TOAST table "pg_toast.pg_toast_49444"
   Column   |  Type
------------+---------
```

```
 chunk_id   | oid
 chunk_seq  | integer
 chunk_data | bytea
Owning table: "public.blog"
Indexes:
    "pg_toast_49444_index" PRIMARY KEY, btree (chunk_id, chunk_seq)
```

1. chunk_id： 用来表示特定TOAST值的OID，可以理解为具有同样 chunk_id 值的所有行组成原表 (也就是此处的blog表) 的TOAST字段的一行数据
2. chunk_seq： 用来表示该行数据在整个数据中的位置
3. chunk_data： 实际存储的数据。

```
postgres=# insert into blog values(1, 'title', '0123456789');
INSERT 0 1
postgres=# select * from blog;
 id | title |  content
----+-------+------------
  1 | title | 0123456789
(1 row)

postgres=# select * from pg_toast.pg_toast_49444;
 chunk_id | chunk_seq | chunk_data
----------+-----------+------------
(0 rows)

postgres=# update blog set content=content||content where id=1;
UPDATE 1
postgres=# select id,title,length(content) from blog;
 id | title | length
----+-------+--------
  1 | title |     20
(1 row)

postgres=# select * from pg_toast.pg_toast_49444;
 chunk_id | chunk_seq | chunk_data
----------+-----------+------------
(0 rows)

postgres=# select id,title,length(content) from blog;
 id | title | length
----+-------+--------
  1 | title |     40
(1 row)

---反复执行，不断扩大
postgres=# select id,title,length(content) from blog;
 id | title |  length
----+-------+----------
  1 | title | 41943040
```

```
(1 row)

---可以看到，当content 的长度为41943040时，pg_toast里面有了数据，并且长度都略小于2K，说明在extended策略下，先启用了压缩，然后才使用行外存储。
postgres=# select chunk_id,chunk_seq,length(chunk_data) from pg_toast.pg_toast_49444;
 chunk_id | chunk_seq | length
----------+-----------+--------
    49458 |         0 |   1996
    49458 |         1 |   1996
    49458 |         2 |   1996
    49458 |         3 |   1996
    49458 |         4 |   1996
    49458 |         5 |   1996
    49458 |         6 |   1996
    49458 |         7 |   1996
    49458 |         8 |   1996
    49458 |         9 |   1996
    49458 |        10 |   1996
    49458 |        11 |   1996
    49458 |        12 |   1996
    49458 |        13 |   1996
    49458 |        14 |   1996
    49458 |        15 |   1996
    49458 |        16 |   1996
    49458 |        17 |   1996
    49458 |        18 |   1996
    49458 |        19 |   1996
    ...
```

我们再来看看标志位，这次就很清楚的看到了HASEXTERNAL。

```
postgres=# select lp, t_xmin, t_xmax, t_ctid,
       infomask(t_infomask, 1) as infomask,
       infomask(t_infomask2, 2) as infomask2
from heap_page_items(get_raw_page('blog', 0)) limit 2;
 lp | t_xmin  | t_xmax  | t_ctid |                          infomask
          |          infomask2
----+---------+---------+--------+-----------------------------------------------------------
----------+----------------------------
  1 |         |         |        |
          |
  2 | 3643921 | 3643922 | (0,3)  |
UPDATED|XMAX_COMMITTED|XMIN_COMMITTED|HASEXTERNAL|HASVARWIDTH |
HOT_UPDATED|HEAP_ONLY_TUPLE
(2 rows)
```

HEAP_HASOID_OLD

这个就很好理解了，是否具有oid，PostgreSQL的系统表中大多包含一个叫做OID的隐藏字段，这个OID也是这些系统表的主键。所谓OID，中文全称就是"对象标识符"，oid的分配来自一个实例的全局变量，每分配一个新的对象，对这个全局变量加一。 当分配的oid超过4字节整形最大值的时候会重新从0开始分配，但这并不会导致类似于事务ID回卷那样严重的影响，值得注意的是，从v12开始default_with_oids参数就没了，The parameter default_with_oids is gone, it had been disabled by default since after PostgreSQL 8.0，并且the default_with_oids parameter cannot be changed to 'on'，可能也是为了性能吧，毕竟每次都去检验重试一遍还是十分耗时的。

```
#define HEAP_HASOID_OLD     0x0008  /* has an object-id field */
```

```
postgres=# show default_with_oids ;
 default_with_oids
-------------------
 off
(1 row)

postgres=# select version();
                                                 version

-------------------------------------------------------------------------------------------
------------------
 PostgreSQL 11.9 on x86_64-pc-linux-gnu, compiled by gcc (GCC) 4.8.5 20150623 (Red Hat
4.8.5-44), 64-bit
(1 row)
postgres=# create table tb3(id int) with oids;
CREATE TABLE
postgres=# insert into tb3 values(1);
INSERT 16440 1
postgres=# select lp, t_xmin, t_xmax, t_ctid,
postgres-#        infomask(t_infomask, 1) as infomask,
postgres-#        infomask(t_infomask2, 2) as infomask2
postgres-# from heap_page_items(get_raw_page('tb3', 0));
 lp | t_xmin | t_xmax | t_ctid |      infomask       | infomask2
----+--------+--------+--------+---------------------+-----------
  1 |    574 |      0 | (0,1)  | XMAX_INVALID|HASOID |
(1 row)
```

HEAP_XMAX_KEYSHR_LOCK & HEAP_XMAX_SHR_LOCK

这仨好基友就是行锁的体现了，在PostgreSQL里面，行锁是存储在磁盘上的，表锁我们可以很方便的通过pg_locks查看，行锁就只能pgrowlocks和pageinspect了。

```
#define HEAP_XMAX_KEYSHR_LOCK 0x0010  /* xmax is a key-shared locker */
#define HEAP_XMAX_EXCL_LOCK   0x0040  /* xmax is exclusive locker */
#define HEAP_XMAX_LOCK_ONLY   0x0080  /* xmax, if valid, is only a locker */
```

```
postgres=# create table mytest2(id int);
CREATE TABLE
postgres=# insert into mytest2 values(1);
INSERT 0 1
postgres=# insert into mytest2 values(2);
INSERT 0 1
postgres=# begin;
BEGIN
postgres=*# select * from mytest2 where id = 1 for key share;
 id
----
  1
(1 row)

postgres=*# select * from mytest2 where id = 2 for update;
 id
----
  2
(1 row)
```

再开一个会话查看

```
postgres=# select lp, t_xmin, t_xmax, t_ctid,
       infomask(t_infomask, 1) as infomask,
       infomask(t_infomask2, 2) as infomask2
from heap_page_items(get_raw_page('mytest1', 0));
ERROR:  relation "mytest1" does not exist
postgres=# select lp, t_xmin, t_xmax, t_ctid,
       infomask(t_infomask, 1) as infomask,
       infomask(t_infomask2, 2) as infomask2
from heap_page_items(get_raw_page('mytest2', 0));
 lp | t_xmin   | t_xmax   | t_ctid |                    infomask                    |
infomask2
----+---------+---------+--------+------------------------------------------------+----
----------------
  1 | 3643931 | 3643934 | (0,1)  | XMIN_COMMITTED|XMAX_LOCK_ONLY|XMAX_KEYSHR_LOCK |
  2 | 3643932 | 3643934 | (0,2)  | XMIN_COMMITTED|XMAX_LOCK_ONLY|EXCL_LOCK         |
UPDATE_KEY_REVOKED
(2 rows)
```

HEAP_COMBOCID

元组的t_cid是组合command id，这个标记，常用来标记本事务内的老记录，在介绍combo cid前，需要先了解下cmin和cmax。

> cmin和cmax位于数据页中每个tuple的头部，用于判断tupel在一个事务内可见性的判断，cmin是产生该条tuple的command id，cmax是删除该tuple的command id。在一个事务内，command id是从0开始递增。一般来说，在PostgreSQL中，判断一条tuple的可见性的时候，通常使用事务当前的snapshot(xmin, xmax, xip*list)*，其中xmin是当前活跃的最小事务id，比这个xmin还是小的事务id要么commit要么rollack。xmax是本事务取snapshot时，还没有分配的最小事务id，也就是说，大于等于xmax的事务id所做的修改，对于当前事务来说都不可见。xip_list是当前活跃事务id列表，当前事务看不到该list中的事务所做修改。但是在同一个事务内的时候，并读取时，就会有点问题了：

```
postgres=# create table test1 (c1 int, c2 int);
CREATE TABLE
postgres=# begin;
BEGIN
postgres=*# insert into test1 values (1,2);
INSERT 0 1
postgres=*# select * from test1;
 c1 | c2
----+----
  1 |  2
(1 row)

postgres=*# commit;
COMMIT
```

> 如果仅仅使用xmin，xmax就无法判断tuple的可见性，因为插入的事务跟查询的事务在同一个事务中。所以，此时使用query的command id去比较tuple上的cmin和cmax。上面的例子中，query的cid为1，tuple(1,2)上cmin为0，cmax为invalid。因此，cid>cmin,同时cmax为invalid，所以query对该tuple可见。
>
> 因此，为了对一个tuple进行事务内部可见性的判读，需要在每个tuple的头部存储两个uint32类型的字段，cmin和cmax。但是，一个tuple在一个事务内被插入然后马上被更新或删除的场景一般比较少，所以一般MVCC判断的时候，比较少走到使用cmin和cmax的逻辑。
>
> 因而，为了减少cmin和cmax对heap page空间的占用，在PG8.3后，将cmin和cmax合并成一个字段，使用1个unit32类型，即combo cid。那么combo cid是如何实现，仅依靠一个字段的存储，在需要cmin的时候提供cmin，而在需要cmax的时候提供cmax呢？对于这个问题，相信通过了解combo cid的逻辑，就可引刃而解。
>
> combo cid逻辑的介绍，这里通过下面几个问题的回答来介绍：
>
> 1. 何时会产生combo cid?
>
> 在一个事务，当新插入一个tuple的时候，实际是不需要使用combo cid的，因为此时只有cmin有效。而只有在一个tuple被update或者delete时，cmax才会产生，此时就需要使用cmax。所以，在刚插入一个tuple的时候，cmin/cmax这个字段就是指示的cmin，只有，在update或者delete的时候，这个域才会是combo cid。

```
postgres=# begin;
BEGIN
postgres=*# insert into test1 values (1,2);
INSERT 0 1
postgres=*# update test1 set c2 = 99 ;
```

```
UPDATE 2
postgres=*# select lp, t_xmin, t_xmax, t_ctid,
       infomask(t_infomask, 1) as infomask,
       infomask(t_infomask2, 2) as infomask2
from heap_page_items(get_raw_page('test1', 0));
 lp | t_xmin   | t_xmax   | t_ctid |       infomask       |    infomask2
----+----------+----------+--------+----------------------+-----------------
  1 | 3643936 | 3643937 | (0,3)  | XMIN_COMMITTED       | HOT_UPDATED
  2 | 3643937 | 3643937 | (0,4)  | COMBOCID             | HOT_UPDATED
  3 | 3643937 |       0 | (0,3)  | UPDATED|XMAX_INVALID | HEAP_ONLY_TUPLE
  4 | 3643937 |       0 | (0,4)  | UPDATED|XMAX_INVALID | HEAP_ONLY_TUPLE
(4 rows)
```

HEAP_XMIN_COMMITTED

```
#define HEAP_XMIN_COMMITTED   0x0100  /* t_xmin committed */
#define HEAP_XMIN_INVALID   0x0200  /* t_xmin invalid/aborted */
#define HEAP_XMIN_FROZEN    (HEAP_XMIN_COMMITTED|HEAP_XMIN_INVALID)
#define HEAP_XMAX_COMMITTED   0x0400  /* t_xmax committed */
#define HEAP_XMAX_INVALID   0x0800  /* t_xmax invalid/aborted */
```

这几个好基友就是用来加速事务获取和冻结相关的，冻结可以参照我之前的文章，在此就不再演示了。

当查询一条数据的时候，需要去判断行的可见性，需要去查询相应事务的提交状态，我们只能从CLOG中或者PGXACT内存结构中(未结束的或未清除的事务信息内存)得知该tuple对应的事务提交状态，显然如果每条tuple都要查询pg_clog的话，性能一定会很差，当然还要根据隔离级别、事务快照来综合判断行的可见性，在此不再赘述，在PostgreSQL中提供了TransactionIdIsInProgress、TransactionIdDidCommit和TransactionIdDidAbort用于获取事务的状态，这些函数被设计为尽可能减少对CLOG的频繁访问 (假如把freeze相关参数设置为20亿的话，那么clog最多可能达到500多MB，每一个事务占2bit) 。尽管如此，如果在检查每条元组时都执行这些函数，也可能会成为瓶颈。

所以，为了解决这个问题，PostgreSQL在t_infomask中使用了相关标志位，如下：

```
#define HEAP_XMIN_COMMITTED   0x0100  /* t_xmin committed */
#define HEAP_XMIN_INVALID   0x0200  /* t_xmin invalid/aborted */
#define HEAP_XMAX_COMMITTED   0x0400  /* t_xmax committed */
#define HEAP_XMAX_INVALID     0x0800  /* t_xmax invalid/aborted */
```

在读取或写入元组时，PostgreSQL会择机将提示为设置到t_infomask中，比如PostgreSQL检查了元组的t_xmin对应事务的状态，结果为commited，那么就会在元组的t_infomask中置位一个HEAP_XMIN_COMMITTED，表示这条元组已经提交了，如果设置了标志位，那么就不再需要去调用TransactionIdDidCommit和TransactionIdDidAbort去获取事务的状态，可以高效地检查每个元组xmin和xmax对应的事务状态。所以，和Oracle一样，一些select操作也会产生写IO，原因就是设置标志位。

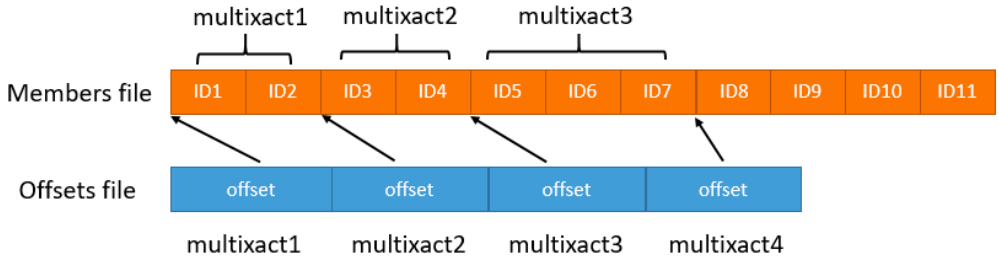
```
postgres=# create table test2(id int);
CREATE TABLE
postgres=# insert into test2 values(1);
INSERT 0 1
```

```
postgres=# select t_xmin,t_xmax,t_infomask,t_infomask2 from
heap_page_items(get_raw_page('test2', 0));
 t_xmin   | t_xmax | t_infomask | t_infomask2
---------+--------+------------+-------------
 3643942 |      0 |       2048 |           1
(1 row)

postgres=# select lp, t_xmin, t_xmax, t_ctid,
       infomask(t_infomask, 1) as infomask,
       infomask(t_infomask2, 2) as infomask2
from heap_page_items(get_raw_page('test2', 0));
 lp | t_xmin   | t_xmax | t_ctid |   infomask    | infomask2
----+---------+--------+--------+---------------+-----------
  1 | 3643942 |      0 | (0,1)  | XMAX_INVALID |
(1 row)

---注意，此处仅有XMAX_INVALID标志位
postgres=# select * from test2;
 id
----
  1
(1 row)

postgres=# select lp, t_xmin, t_xmax, t_ctid,
       infomask(t_infomask, 1) as infomask,
       infomask(t_infomask2, 2) as infomask2
from heap_page_items(get_raw_page('test2', 0));
 lp | t_xmin   | t_xmax | t_ctid |          infomask            | infomask2
----+---------+--------+--------+------------------------------+-----------
  1 | 3643942 |      0 | (0,1)  | XMAX_INVALID|XMIN_COMMITTED |
(1 row)

---添加了XMIN_COMMITTED的标志位
```

但是需要注意的是，并不是在事务结束时设置t_infomask的标志位，而是等到后面的DML或者DQL，VACUUM等SQL扫描到对应的TUPLE时，触发置位的操作，是不是大有前人拉屎后人擦屁股的赶脚？？

HEAP_XMAX_IS_MULTI

也就是multixact，因为对于FOR SHARE和FOR KEY SHARE这一类的行级锁，一行上面可能会被多个事务加锁，Tuple上动态维护这些事务代价很高，为此引入了multixact机制，将多个事务记录到MultiXactId，再将MultiXactId记录到tuple的xmax中。



Members文件中每4个一组，会有一个4byte的flag,每组bytes,offsets中记录的offset要经过计算才能得到真实members中的起始位置
源码位置
Backend/access/transam/multixact.c

```
/*
 * The situation for members is a bit more complex: we store one byte of
 * additional flag bits for each TransactionId.  To do this without getting
 * into alignment issues, we store four bytes of flags, and then the
 * corresponding 4 Xids.  Each such 5-word (20-byte) set we call a "group", and
 * are stored as a whole in pages.  Thus, with 8kB BLCKSZ, we keep 409 groups
 * per page.  This wastes 12 bytes per page, but that's OK -- simplicity (and
 * performance) trumps space efficiency here.
 *
 * Note that the "offset" macros work with byte offset, not array indexes, so
 * arithmetic must be done using "char *" pointers.
 */
/* We need eight bits per xact, so one xact fits in a byte */
#define MXACT_MEMBER_BITS_PER_XACT          8
#define MXACT_MEMBER_FLAGS_PER_BYTE         1
#define MXACT_MEMBER_XACT_BITMASK   ((1 << MXACT_MEMBER_BITS_PER_XACT) - 1)

/* how many full bytes of flags are there in a group? */
#define MULTIXACT_FLAGBYTES_PER_GROUP       4
#define MULTIXACT_MEMBERS_PER_MEMBERGROUP   \
    (MULTIXACT_FLAGBYTES_PER_GROUP * MXACT_MEMBER_FLAGS_PER_BYTE)
/* size in bytes of a complete group */
#define MULTIXACT_MEMBERGROUP_SIZE \
    (sizeof(TransactionId) * MULTIXACT_MEMBERS_PER_MEMBERGROUP + MULTIXACT_FLAGBYTES_PER_GROUP)
#define MULTIXACT_MEMBERGROUPS_PER_PAGE (BLCKSZ / MULTIXACT_MEMBERGROUP_SIZE)
#define MULTIXACT_MEMBERS_PER_PAGE  \
    (MULTIXACT_MEMBERGROUPS_PER_PAGE * MULTIXACT_MEMBERS_PER_MEMBERGROUP)
```

```
postgres=# begin;
BEGIN
postgres=*# select txid_current();
 txid_current
--------------
      3643949
(1 row)

postgres=*# select * from test3 where id = 1 for key share;
 id
----
  1
(1 row)
```

查看行锁

```
postgres=# select * from test3 as t,pgrowlocks('test3') as lc where t.ctid =
lc.locked_row;
 id | locked_row | locker  | multi |   xids    |       modes        |  pids
----+------------+---------+-------+-----------+--------------------+---------
  1 | (0,1)      | 3643949 | f     | {3643949} | {"For Key Share"} | {18215}
(1 row)
```

再开一个事务，加上行锁

```
postgres=# begin;
BEGIN
postgres=*# select txid_current();
 txid_current
--------------
      3643951
(1 row)

postgres=*# select * from test3 where id = 1 for share;
 id
----
  1
(1 row)
```

再次查看行锁，可以看到multi字段为true了

```
postgres=# select * from test3 as t,pgrowlocks('test3') as lc where t.ctid =
lc.locked_row;
 id | locked_row | locker | multi |       xids        |        modes         |     pids

----+------------+--------+-------+-------------------+----------------------+----------
-----
  1 | (0,1)      |      1 | t     | {3643949,3643951} | {"Key Share",Share} |
{18215,18267}
(1 row)
postgres=# select lp, t_xmin, t_xmax, t_ctid,
       infomask(t_infomask, 1) as infomask,
       infomask(t_infomask2, 2) as infomask2
from heap_page_items(get_raw_page('test3', 0));
 lp | t_xmin   | t_xmax | t_ctid |                                infomask
                 | infomask2
----+----------+--------+--------+-------------------------------------------------------
------------------+-----------
  1 | 3643944 |      1 | (0,1)  |
XMAX_IS_MULTI|XMIN_COMMITTED|XMAX_LOCK_ONLY|EXCL_LOCK|XMAX_KEYSHR_LOCK |
  2 | 3643945 |      0 | (0,2)  | XMAX_INVALID|XMIN_COMMITTED
                 |
  3 | 3643946 |      0 | (0,3)  | XMAX_INVALID|XMIN_COMMITTED
                 |
(3 rows)
```

可以通过pg_get_multixact_members获取multixact

```
postgres=# select * from pg_get_multixact_members('1');
   xid    | mode
---------+-------
 3643949 | keysh
 3643951 | sh
(2 rows)
```

其他

其他几个infomask标志位就不再赘述了，下面这俩标志位保留用于pg_upgrate使用

```
#define HEAP_MOVED_OFF      0x4000  /* moved to another place by pre-9.0
                     * VACUUM FULL; kept for binary
                     * upgrade support */
#define HEAP_MOVED_IN     0x8000  /* moved from another place by pre-9.0
                     * VACUUM FULL; kept for binary
                     * upgrade support */
#define HEAP_MOVED (HEAP_MOVED_OFF | HEAP_MOVED_IN)
```

update产生的元组

```
#define HEAP_UPDATED      0x2000  /* this is UPDATEd version of row */
```

这个和可见性有关了，不过愚笨的我暂未复现什么条件会触发这个标志位的设置，再琢磨琢磨。

```
#define HEAP_XACT_MASK      0xFFF0  /* visibility-related bits */
```

小结

另外我们需要注意的是，标志位还和wal_log_hints有关

1. 假设未开启checksum，开启了wal_log_hints,第一次使页面变脏的操作是修改hint bints,会记录整页到wal中
2. 假设开启了checksum，不管wal_log_hints如何，checkpoint后第一次修改的页面都会记录整页到wal中。即使是hint bits
3. 假设未开启wal_log_hints，第一次使页面变脏的操作是修改hint bints，不会记录full page image
4. 可见，在启用 checksum 的情况下，checkpoint 后页面的第一次修改如果是更新 Hint Bits， 会写 Full Page Image 至 WAL 日志，这会导致 WAL 日志占用更多的存储空间。

同时，还有一种可能性，因为SetHintBits是针对单条tuple的，所以当有并行的会话在对一个数据页的多个tuple进行SetHintBits操作时，可能导致这个PAGE在多次checkpoint时被写多次到WAL。或者在2个checkpoint之间，多次被bgwriter刷到OS dirty page，可能造成多次OS IO。

以上种种演示了hint bits的作用，可以看到好处很多，并且可以用这个去面试小白：select是否会产生写IO？(坏笑ing...)

参考

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