IMS DB Basics
E02

Anaheim, California October 23 - 27, 2000

Roderick G. Murchison
IMS Service Delivery, Santa Teresa Lab

RETURN TO INDEX

Contents

Contents

Contents

Database Basics

TOPIC

Database Basics

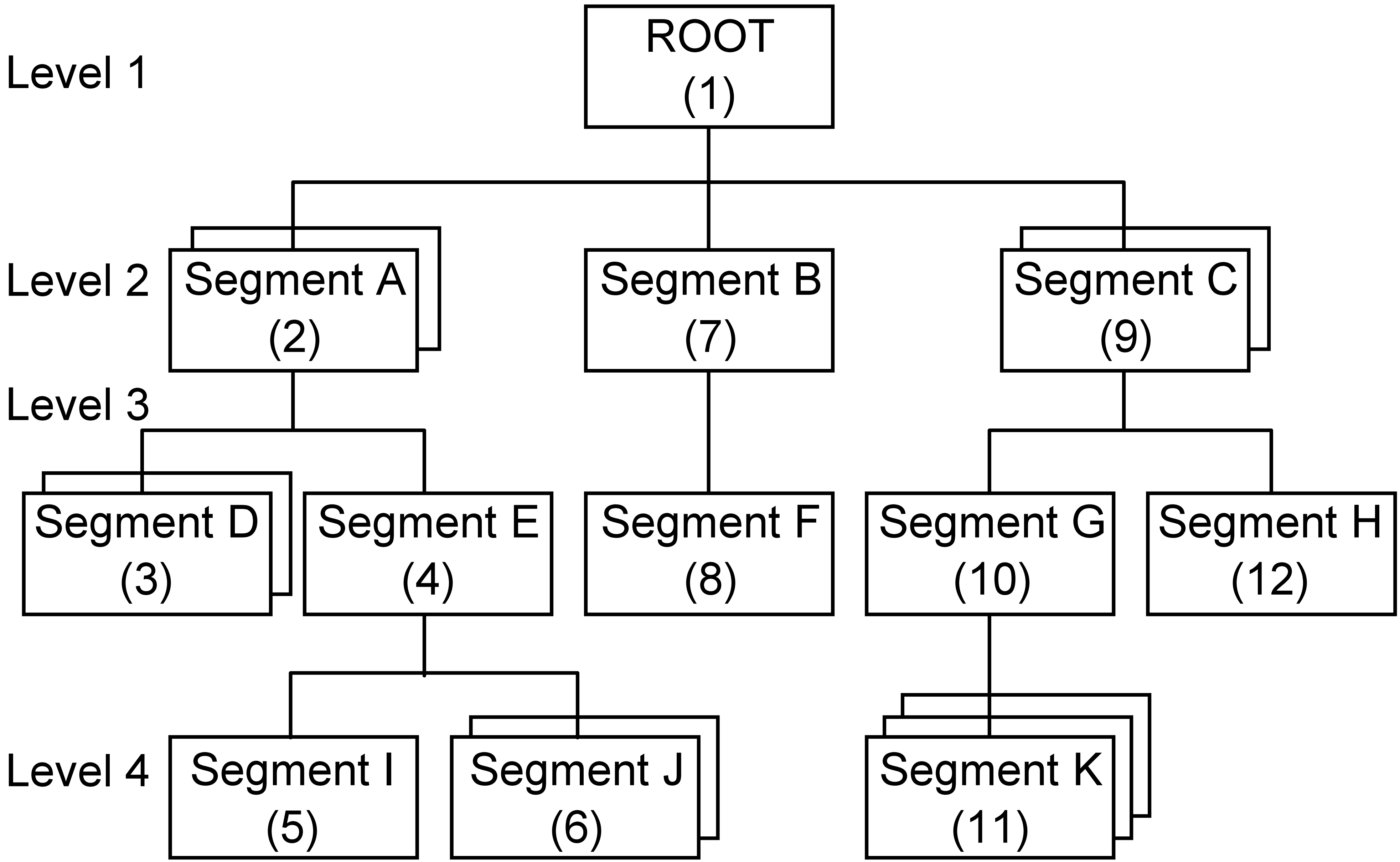
What is a Database

- A collection of interrelated data items organized in a form for easy retrieval
  - The collection of data is stored in a computer system
  - The retrieval is done by application programs
  - Each item of data only needs to be stored once
    - Shared among the programs and users
- An IMS database is organized as a hierarchy
  - Levels of data
  - Data at lower levels depends on data at higher levels for its context
    - You cannot understand the lower level without knowing the higher levels

The IMS Database

- A database is a group of related database records
- A database record is a single hierarchy of related segments
- A segment is a group of related fields
- A field is a single piece of data
  - It can be used as a key for ordering the segments
  - It can be used as a qualifier for searching
  - It may only have meaning to the applications
- IMS database always look like hierarchies

The Hierarchy



Segment Rules

Root

- One and only one root for each database record
- No higher level segments
  - Everything depends on the information in the root

Other Segment Types

- Up to 254 different segmet types
  - 255 including the root
- Any number of occurrences of each segment type
- Each segment, except the root, is related to one and only one segment at the next higher level

Segment Relationships

Parent

All segments which have dependent segments at the next lower level are parents of those segments

A parent may have any number of dependent segments

Child

A segment which depends on a segment at a higher level is a child of that segment

Every child segment has one and only one present

Twins

All occurrences of a segment type under the same parent are twins

There may be any number of twins and they are still called twins

Siblings

Segments of different types with the same parent are siblings

Hierarchic Sequence

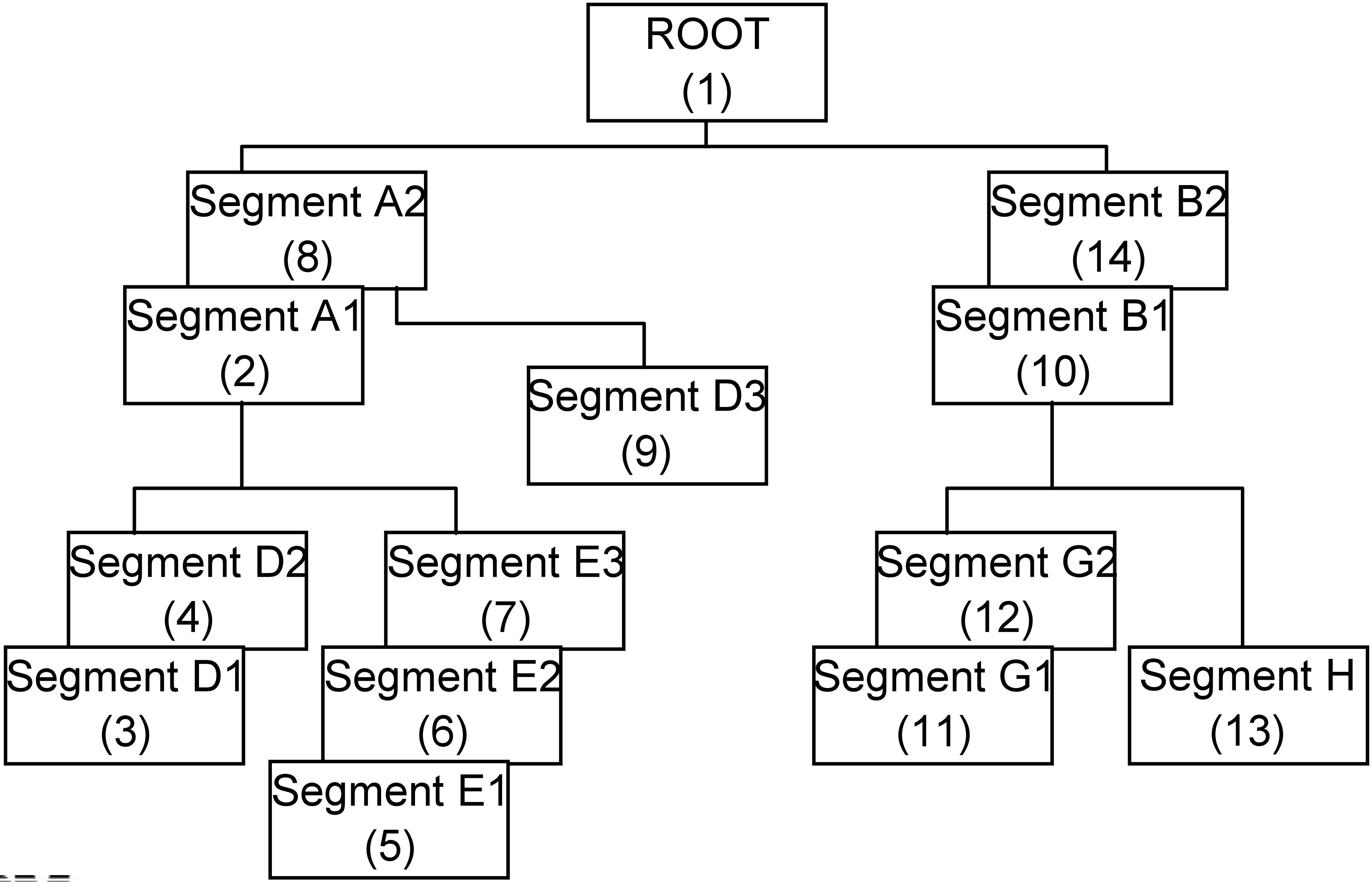
Top to Bottom

Left to Right

Front to Back (for twins)

- Each segment TYPE has a code which is its number in hierarchic sequence
  - Segment codes numbers do not take twins into account
- Sequential processing of a database record is in hierarchic sequence
  - All segments of a database record are included so twins do have a place in hierarchic sequence
- Segments may contain sequence fields which will determine the order in which they are stored and processed

Hierarchic Sequence ...



Access to Segments

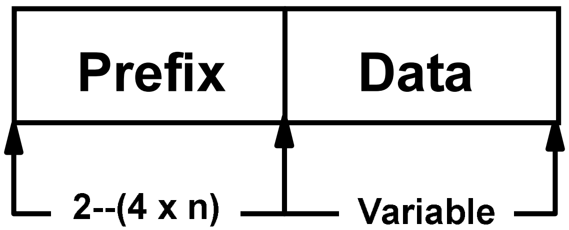
Retrieval

- Get Unique (GU)
  - Read a particular segment as determined by sequence or search fields
- Get Next (GN)
  - Read the next segment in hierarchic sequence
- Get Next Within Parent (GNP)
  - Read the next segment in hierarchic sequence under a particular parent segment

Update

- Insert (ISRT)
  - Insert a new occurrence of a segment
- Delete (DLET)
  - Delete a segment
- Replace (REPL)
  - Update a segment with a new data, except for the sequence field

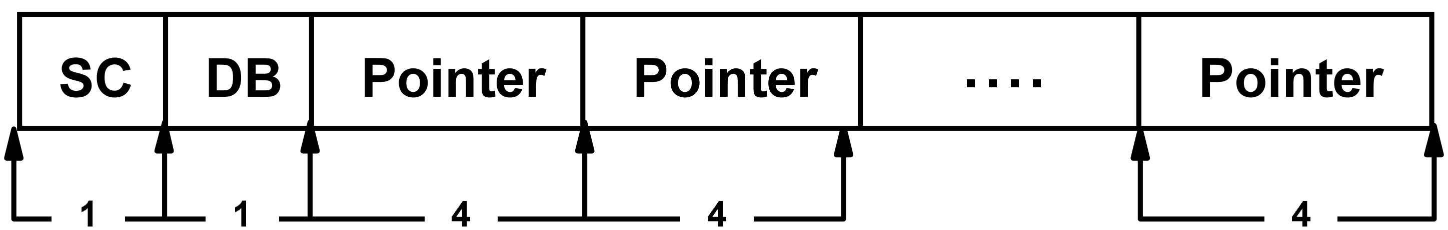
Segments in Storage



Segments are stored with a prefix and a data portion

The prefix is used only by IMS

The data is what the application program sees



- **The prefix contains:**
  - **SC = segment code, 1 byte**
  - **DB = delete byte, 1 byte**
  - **0 to n pointers, 4 bytes each**

Sequential Organization

TOPIC

Sequential Organization

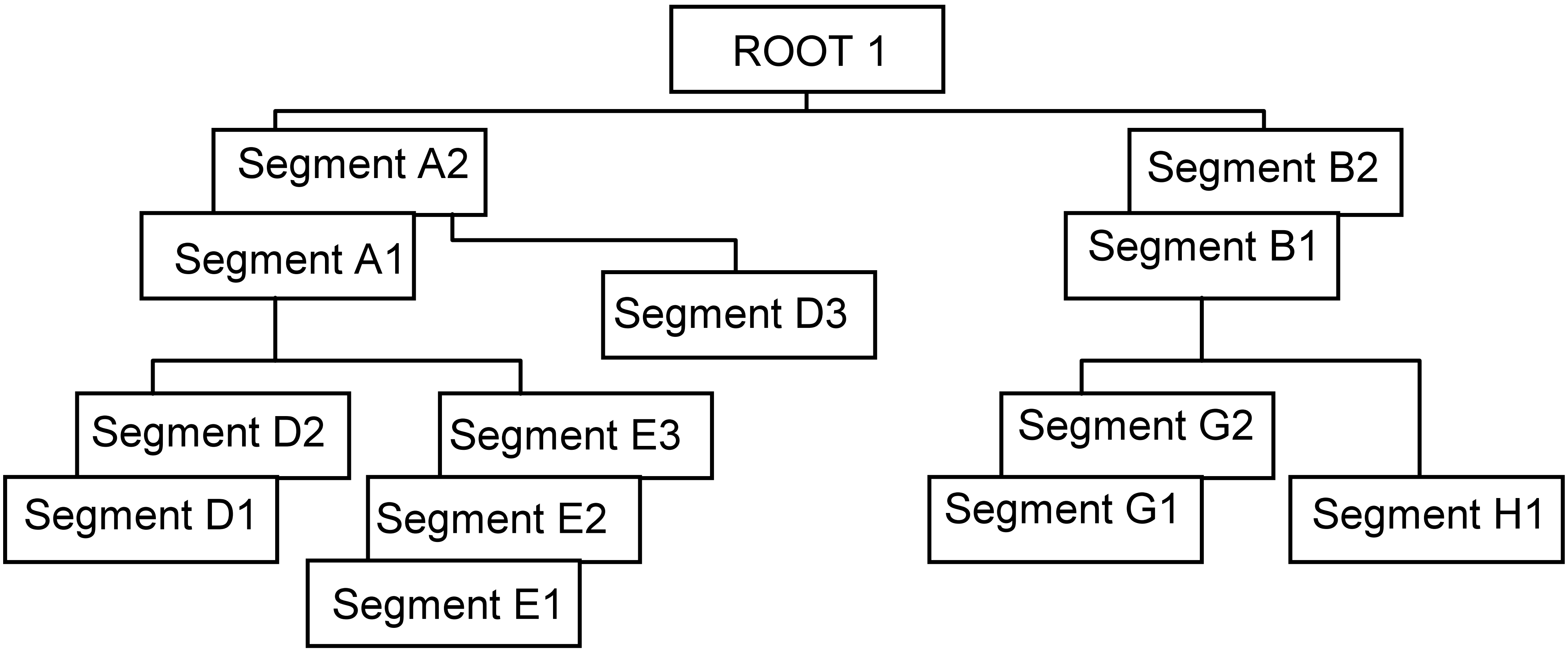
Sequential Organization

- The data is physically stored in hierarchic sequence
  - Database records are stored in a root key sequence
    - If no root key, they are stored as presented
  - Segments in a record are stored in hierarchic sequence
- Sequential Database Types
  - Hierarchic Sequential Access Method (HSAM)
  - Simple Hierarchic Sequential Access Method (SHSAM)
    - Root-only HSAM
  - Hierarchic Indexed Sequential Access Method (SHISAM)
    - Root-only HISAM using VSAM
  - Generalized Sequential Access Method (GSAM)
    - No hierarchy, no database records, no segments

HSAM

- Tape or DASD
- BSAM or QSAM
  - QSAM if online or PROCOPT=GS
- Fixed-Length, Unblocked format
  - RECFM=F, logical record length=physical block size
- Cannot Delete or Replace
  - Update by rewriting the database
- Insert allowed when loading the database
- Restrictions
  - No pointers in prefix - SC and DB only
    - Delete byte is not used
  - No multiple data set groups (MSDG)
  - No logical relationships or secondary indices
  - No variable length segments
  - No edit/compression or data capture
  - No logging, recovery, or reorganization

HSAM Storage



Root 1	A1	D1	D2	E1	00

Block 1

E2	E3	A2	D3	B1	G1	0

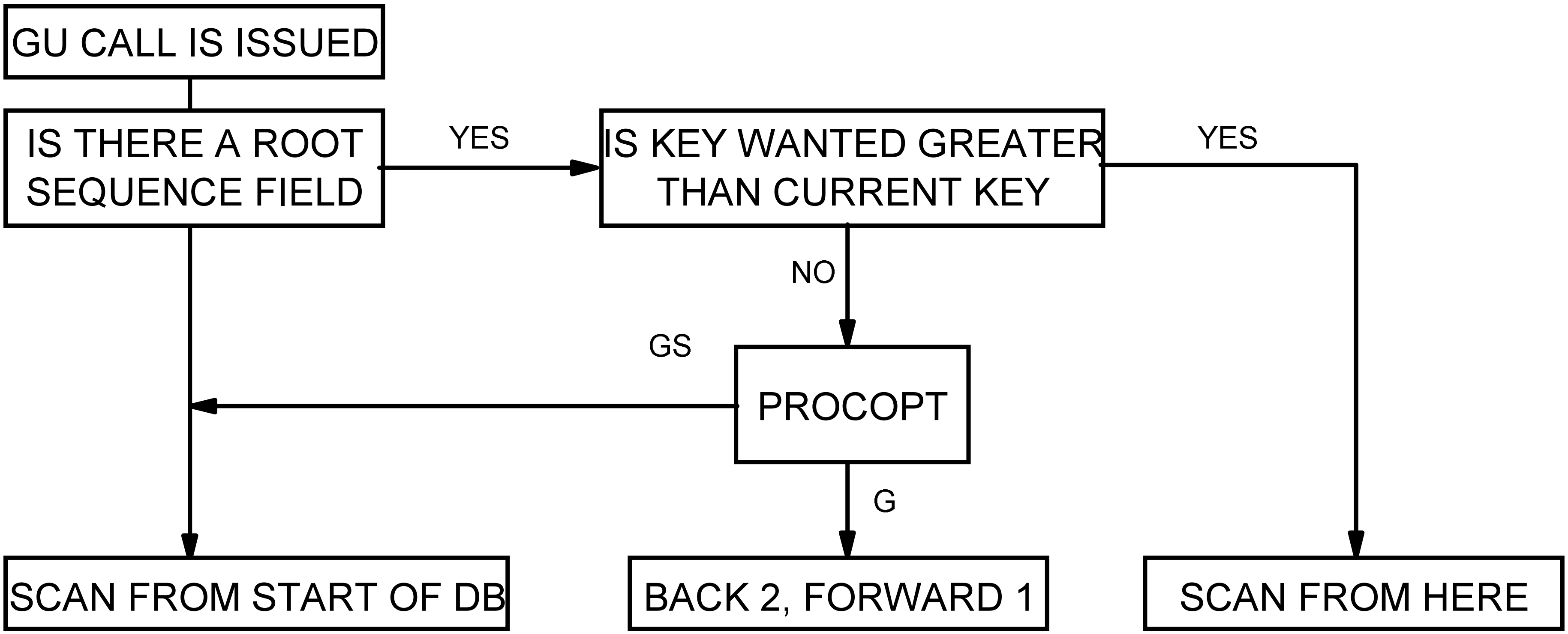
Block 2

G2	G3	H1	Root 2	...	00

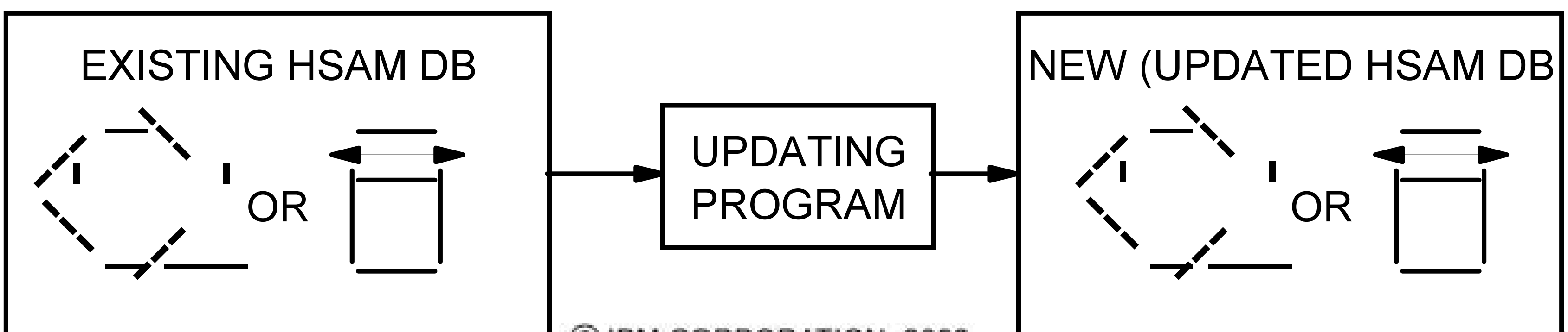
Block 3

HSAM Processing

Retrieval



- **Update**

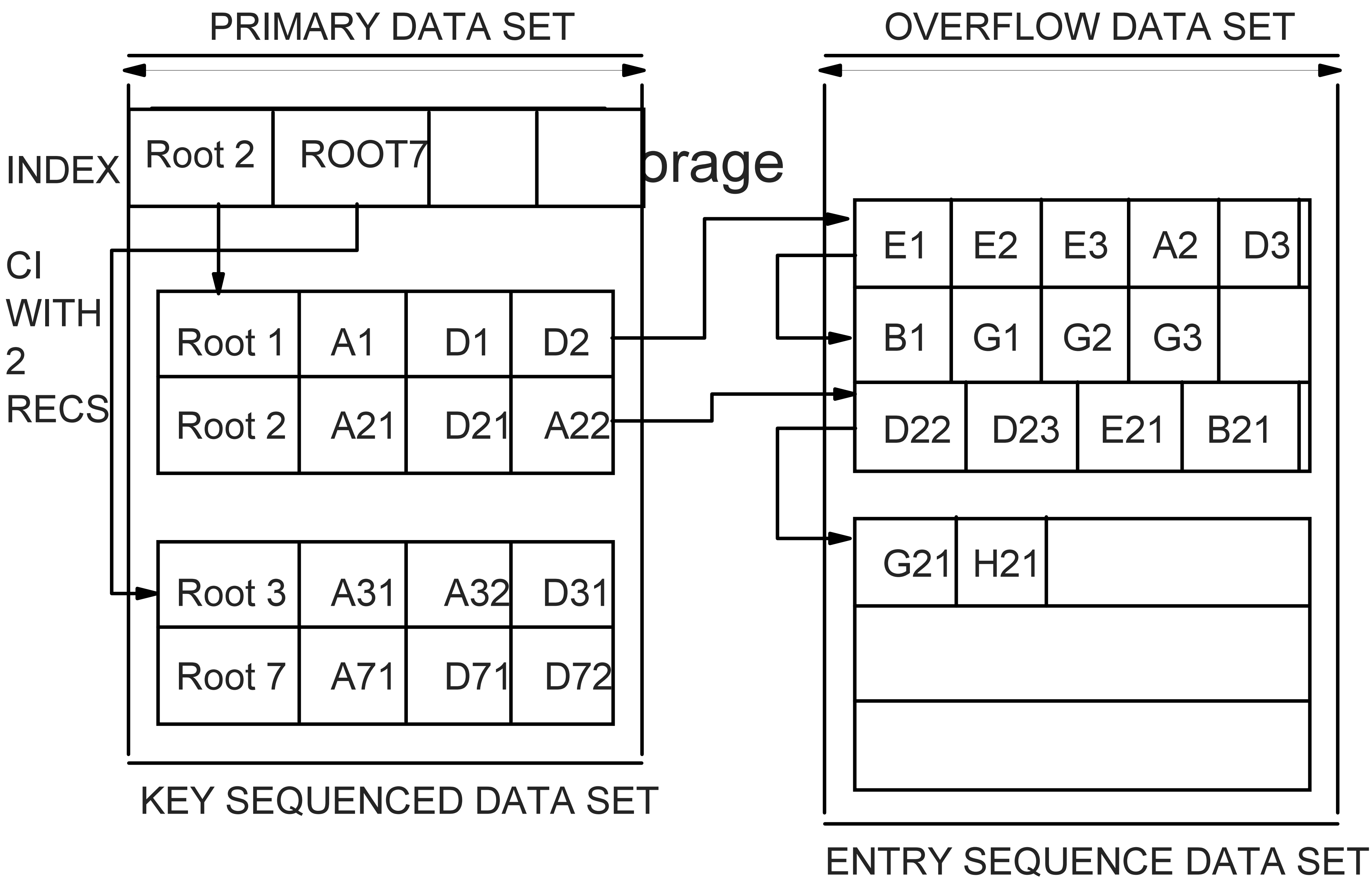


SHSAM

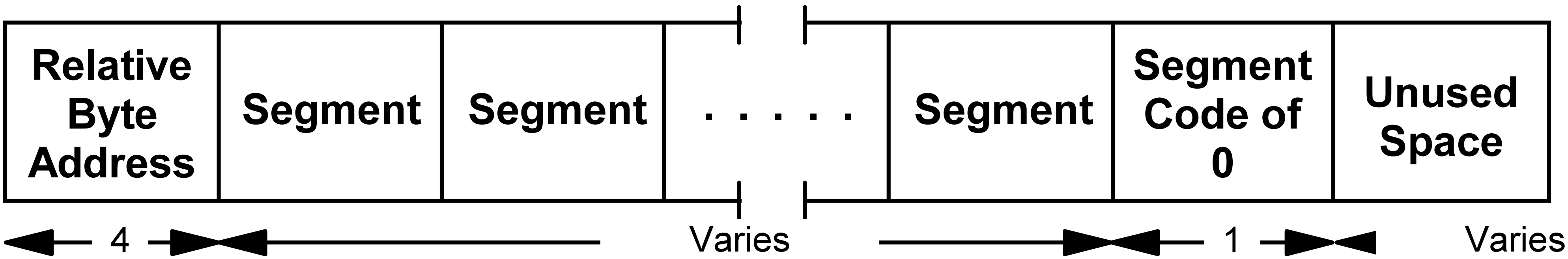
- HSAM with only one segment type (root-only)
  - No prefix is used
    - No SC because only one segment type
    - DB is not used by HSAM anyway
- Same restrictions and processing as HSAM
- Fully equivalent to plain QSAM or BSAM file
  - Communication with non-IMS systems
  - Passing large amounts of data

HISAM

- DASD only
- VSAM
  - KSDS for the primary data set
  - EDS for the overflow data set
- Each root must have a unique key
- A database record is stored as 1 record in the primary data set and 0 to N records in the overflow data set
- All calls are allowed
- Prefix consists of SC and DB
- HSAM restriction do not apply
- HISAM works better when
  - Applications randomly access the records and then read the segments sequentially
  - Most of the database records are the same size
  - Relatively few dependents per root
  - Very low insert/delete activity


PRIMARY DATA SET
OVERFLOW DATA SET
INDEX
Root 2
ROOT7
orage
CI
WITH
2
RECS
Root 1
A1
D1
D2
Root 2
A21
D21
A22
Root 3
A31
A32
D31
Root 7
A71
D71
D72
E1
E2
E3
A2
D3
B1
G1
G2
G3
D22
D23
E21
B21
G21
H21
KEY SEQUENCED DATA SET
ENTRY SEQUENCE DATA SET

HISAM VSAM Logical Record



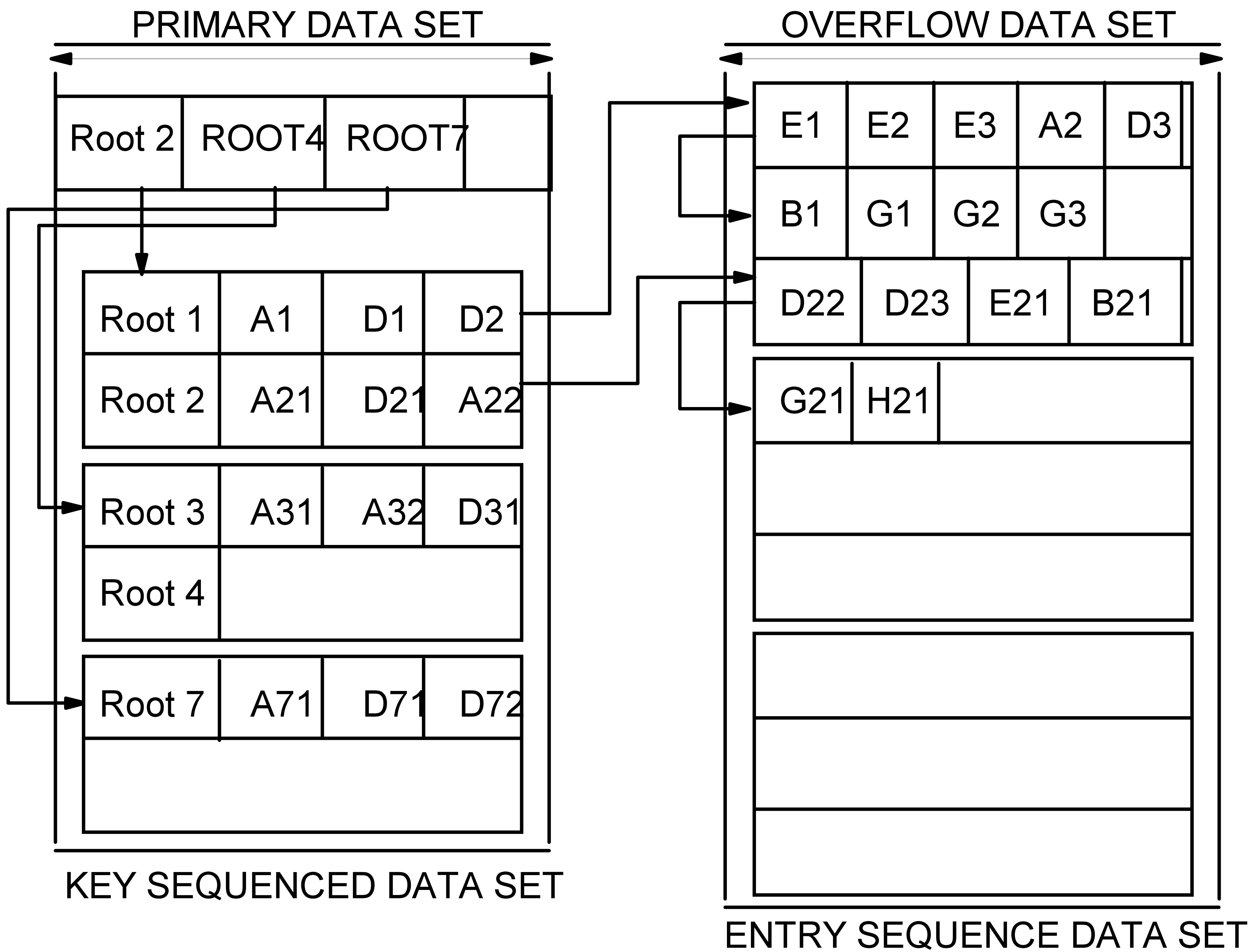
- RBA pointer to the next logical record for this database record
  - Last logical record for DB record has zeros
- Segments are stored in hierarchic sequence
- SC of zero indicates end of segments in this logical record
- Unused space can have any data in it

HISAM Inserts

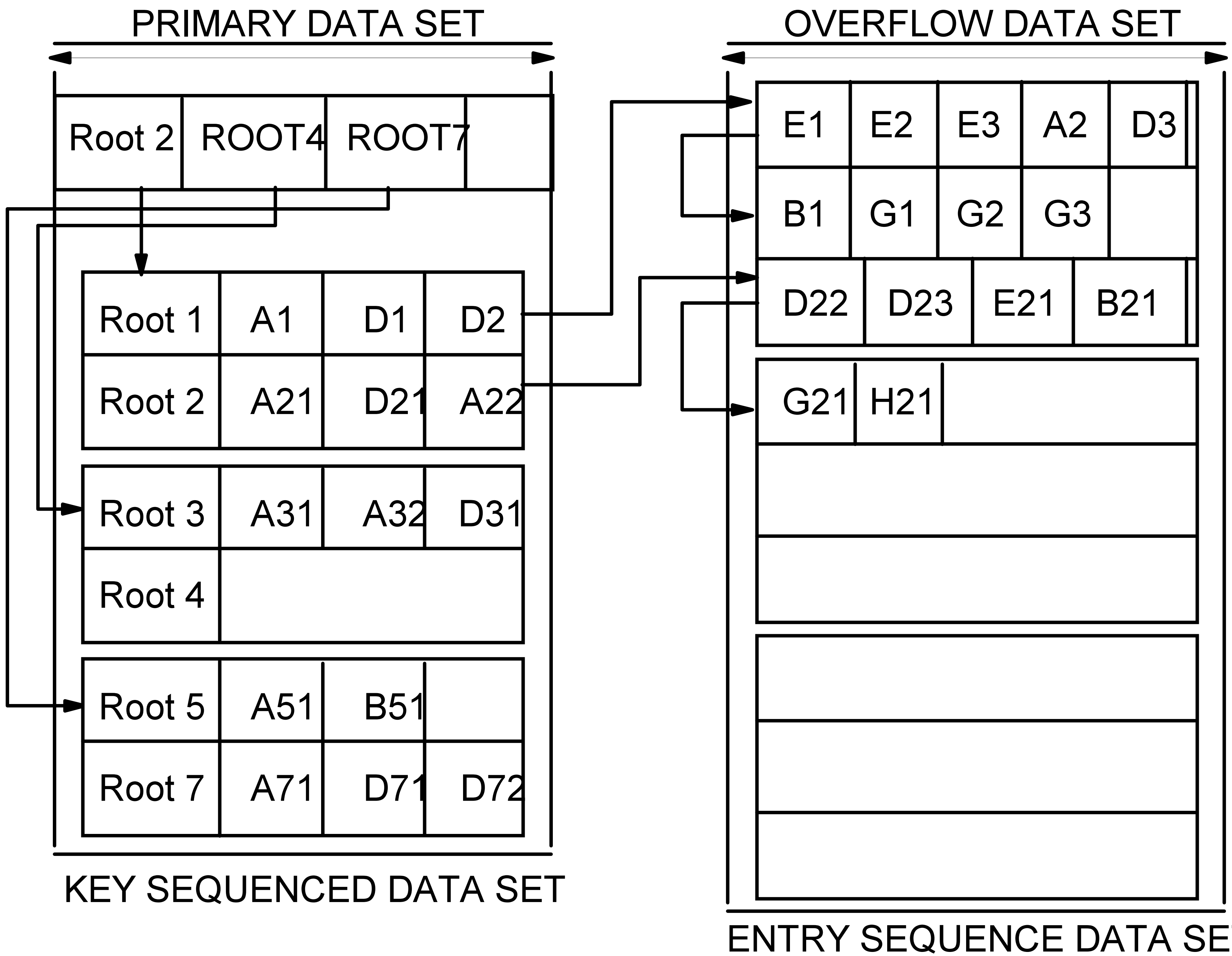
HISAM Roots are always inserted into the Primary Data Set (KSDS)
- If there is an free record in the VSAM Control Interval (CI)
  - Inserted in root key sequence
  - Higher keys are 'pushed down' to make space
- If there is no free record in the CI
  - CI is split - some of the records moved to a new CI
    - - Split at midpoint or insert point by INSERT = in DFSVSAMP
  - After split, same as free record case

Dependents are inserted in their place in hierarchic sequence
- If there is room in the logical record
  - Following are 'pushed down' to make space
- If there is not enough room
  - All following segments are moved to a new overflow record
  - Overflow records chain is updated
  - Segment is inserted

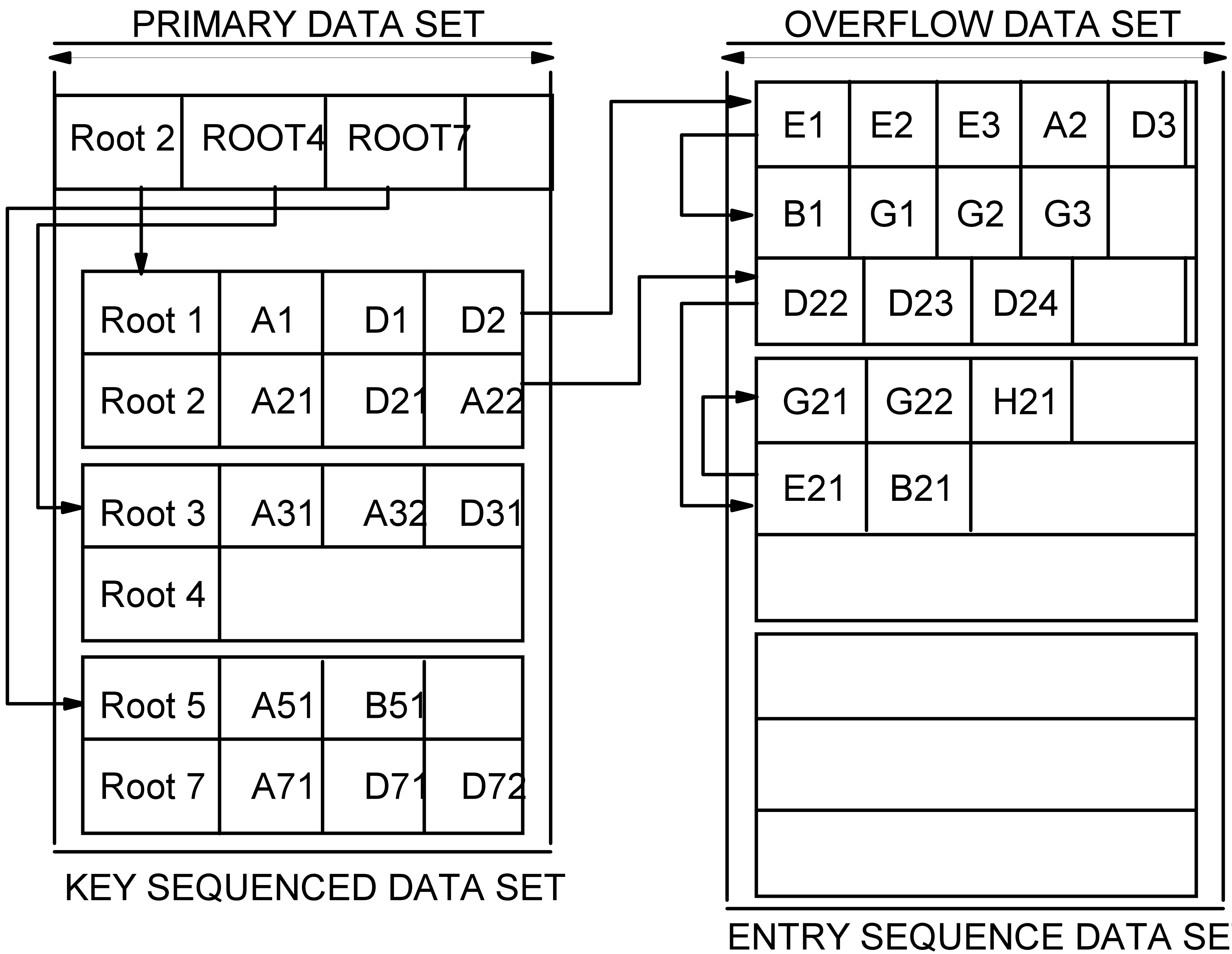
Insert Root 4



Insert Root 5



Insert Dependents G22 and D24



HISAM Delete and Replace

- Delete
  - Marked as deleted in the Delete Byte in prefix
    - Dependents are not flagged but can't be accessed
  - Continue to take up space
    - Unload/Reload to reclaim space
  - If the root is deleted and no logical relationship exists
    - The record is deleted from the primary data set
    - Overflow records continue to exist in the overflow
- Replace
  - Fixed length or same length
    - Overwrite previous data
  - Variable length
    - Other segments in the record move to make space
    - Displaced segments will go to a new overflow record

SHISAM

- HISAM with only one segment type (root-only)
  - No prefix is used
    - No SC because only one segment type
    - No DB because logical record is deleted
- Restrictions
  - No logical relationships or secondary indices
  - No multiple data set groups
  - No variable length segments
  - No edit/compression
- Fully equivalent to a VSAM KSDS
  - No ESDS because no dependent overflow
  - Can be accessed by native VSAM programs

GSAM

- Compatible with MVS data sets
  - No hierarchy
  - No database records
  - No segments and no keys
- GSAM VSAM
  - ESDS on DASD
  - Fixed or variable length records
- GSAM QSAM/BSAM
  - Physical sequential (DSORG=PS) on DASD or Tape
  - Fixed, variable, or undefined length records
- GSAM Processing
  - No Delete or Replace
  - Insert only at the end of the data set
  - Gets by sequential scan

GSAM ...

Restrictions

- No multiple data set groups
- No logical relationships or secondary indices
- No edit/compression or data capture
- No field level sensitivity
- No logging or reorganization

Checkpoint and Restart

- IMS symbolic checkpoint supports GSAM
- Can restart from checkpoint instead of reprocessing
- Restart repositions in the GSAM data set

Direct Organization

TOPIC

Direct Organization

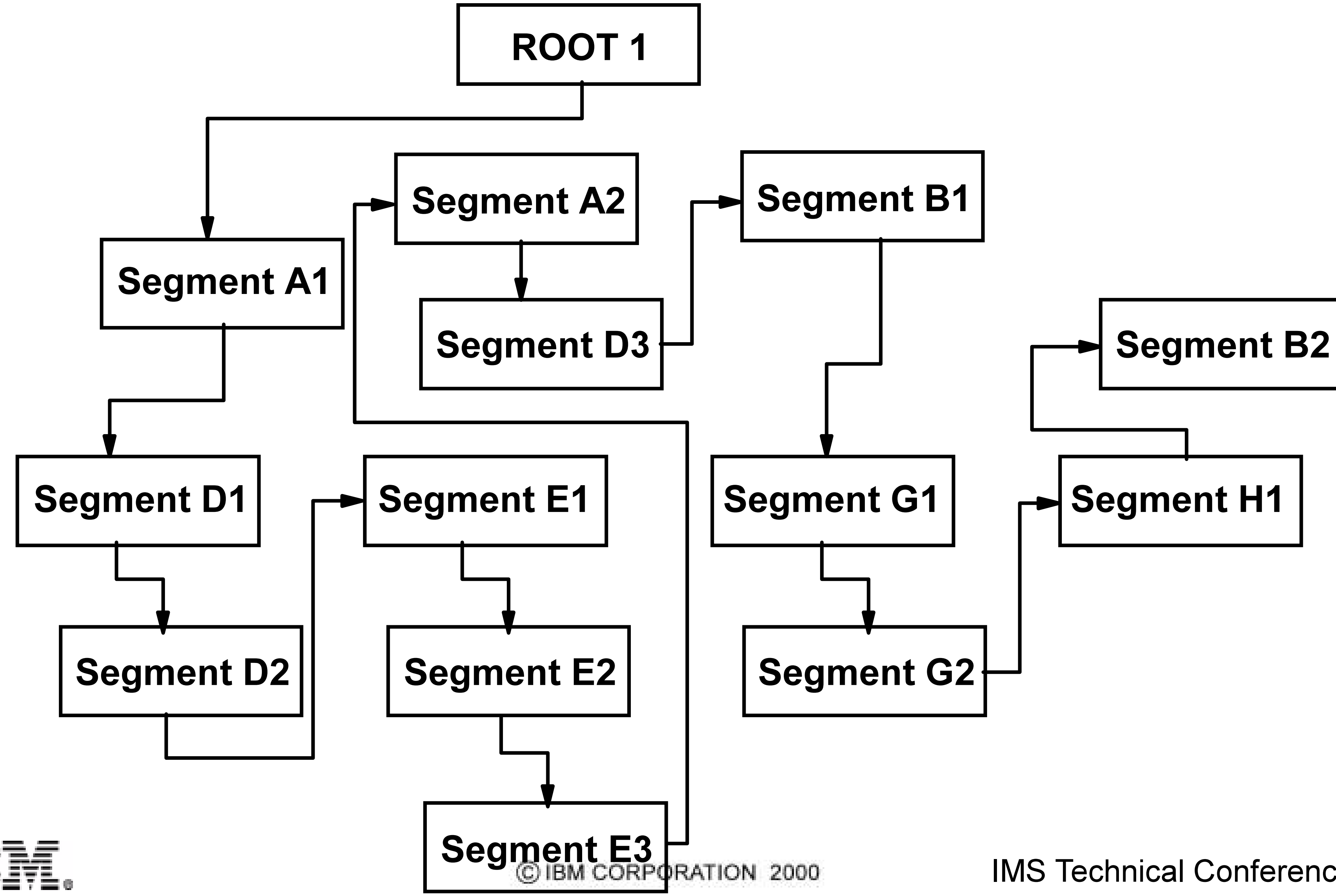
Direct Organization

- Physical storage is independent of hierarchic sequence
  - Pointers are used to maintain segment relationships
    - Pointers are in the segment prefix
    - Segments can be stored 'anywhere'
    - Segments are not physically moved
  - Space from deleted segments can be reused
- Direct Database Types
  - Hierarchic Direct Access Method (HDAM)
    - Uses a randomizing module for direct access to root
  - Hierarchic Indexed Direct Access Method (HIDAM)
    - Searches an index to find the root

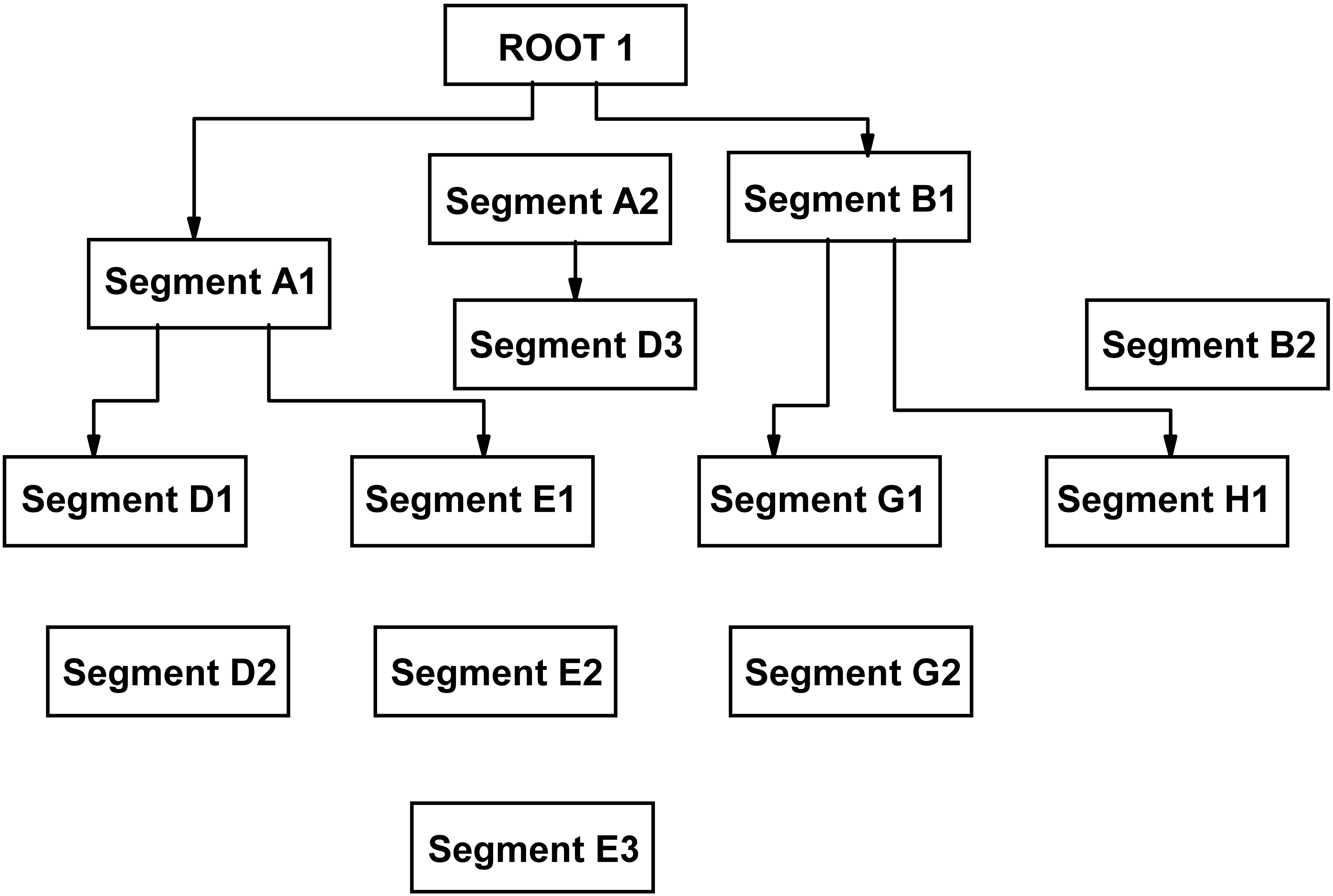
Pointer Types

- Hierarchic
  - May be present in all segment types
  - Forward (HF)
    - Points to next segment in hierarchic sequence
  - Backward (HB)
    - Points to previous segment in hierarchic sequence
    - Must also have HF pointers
- Physical Child
  - Found only in the prefix of a parent segment
  - First (PCF)
    - Points to the first occurrence of a child segment type
    - Must also have PCF pointer
- Twin
  - Forward (PTF)
    - Points to the next twin in key or entry sequence
  - Backward (PTB)
    - Points to the previous twin
    - Must also have PTF pointer

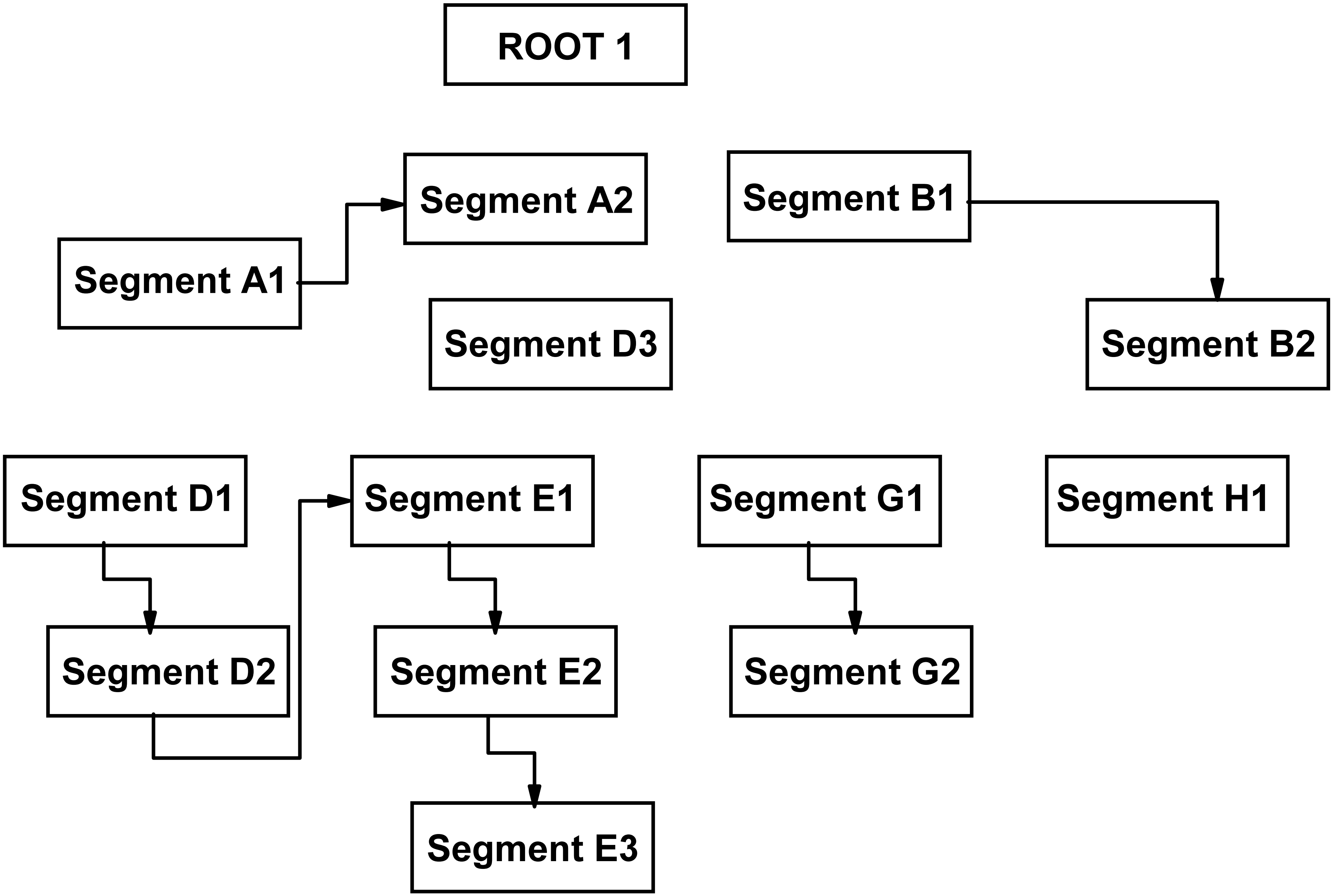
Hierarchic Forward Pointers



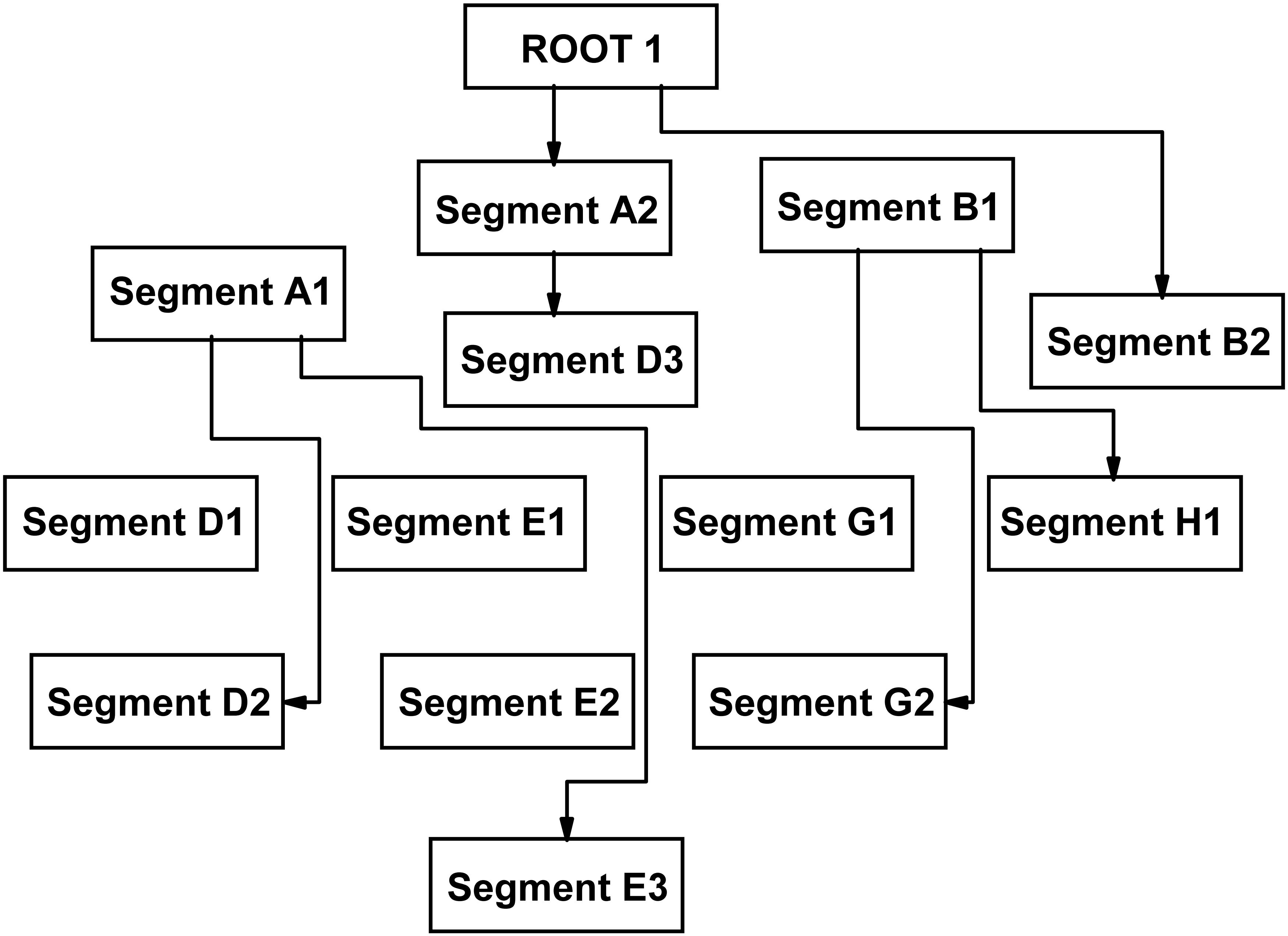
Physical Child First Pointers



Physical Twin Pointers



Physical Child Last Pointers



Coding Pointers in the DBD

- Child Pointers
  - SEGM NAME=A,PARENT=0
    - No child pointers, no parent
  - SEGM NAME=B,PARENT=((A,SNGL))
    - Specifies PCF pointer in parent's prefix - default
  - SEGM NAME=C,PARENT=((A,DBLE))
    - Specifies PCF and PCL in parent's prefix
- Twin Pointers
  - SEGM NAME=X,...,PTR=TWIN
    - Specifies PTF in the prefix of this segment - default
  - SEGM NAME=X,...,PTR=TWINBWD
    - Specifies PTF and PTB in the prefix of this segment
  - SEGM NAME=X,...,PTR=NOTWIN
    - No twin pointers at all. Only one occurrence under parent
- Hierarchic Pointers
  - SEGM NAME=Y,...,PTR=HIER
    - Specifies HF pointer in the prefix of this segment
  - SEGM NAME=Y,...,PTR=HIERBWD
    - Specifies HF and HB pointers in the prefix of this segment

Pointer Uses

- Hierarchic Forward
  - Primary processing is in hierarchic sequence
- Hierarchic Backward
  - Delete activity via a logical relationship or secondary index
- Physical Child First
  - Random processing
  - Sequence field or insert rule FIRST or HERE
- Physical Child Last
  - No sequence field and insert rule LAST
  - Use of *L command code
- Physical Twin Forward
  - Random processing
  - Needed for HDAM roots
  - Poor choice for HIDAM roots
- Physical Twin Backward
  - Improves delete performance
  - Processing HIDAM roots in key sequence

Pointers in the Prefix

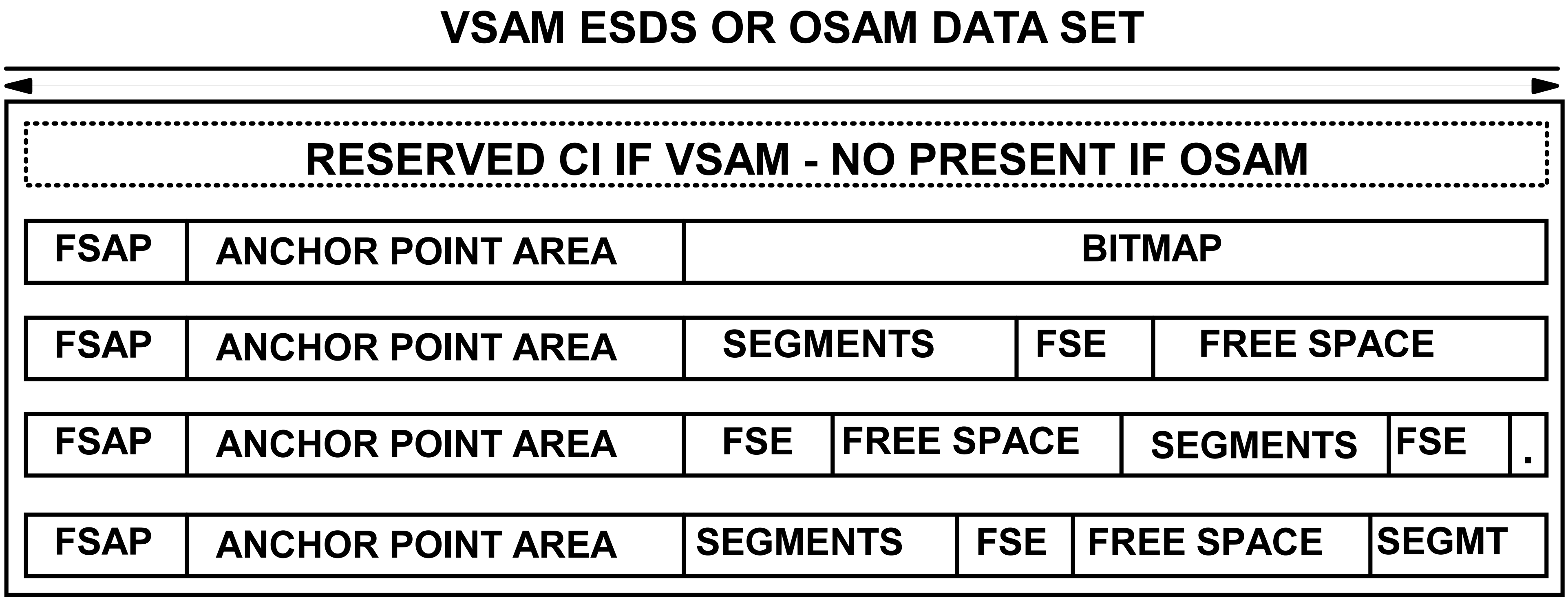
HF	HB

or

PTF	PTB	PCF	PCL

- Cannot have Hierarchic and Physical in the same prefix
  - PTR=H will cause PCF specification to be ignored
- If a parent has PTR=H, children cannot use backward pointers
- If a parent has PTR=HB, children must use backward pointers
- Child pointers will behave like the parent specification
  - Parent hierarchic, last twin pointer goes to sibling, not 0
  - Parent twin, last hierarchic pointer in twins is 0

HD Storage



- All HD data is in a single ESDS or OSAM data set
- The logical records are unblocked
  - Logical record length = block size for OSAM
  - Logical record length = block size -7 for VSAM
- All segments are stored as an even number of bytes

Special HD Fields

- Bitmap
  - One bit per block or CI
    - First bit corresponds to the bitmap itself
  - 1 = enough space to store the LONGEST segment in the database
  - 0 = not enough space for the LONGEST segment
  - If bitmap has N bits, block or CI N + 1 is a new bitmap
- Free Space Anchor Point (FSAP)
  - Two 2-byte fields
    - First the offset from in bytes to first FSE
    - Second is a flag indicating if this block is a bitmap
      0 = this is not a bitmap
- Anchor Point Area
  - Contains one or more 4-byte Root Anchor Points (RAP)
    - 1 RAP in HIDAM if the root has PTF or HF pointer
    - RMNAME parameter specifies number of RAPs in HDAM
  - Each RAP contains the address of a root segment or 0

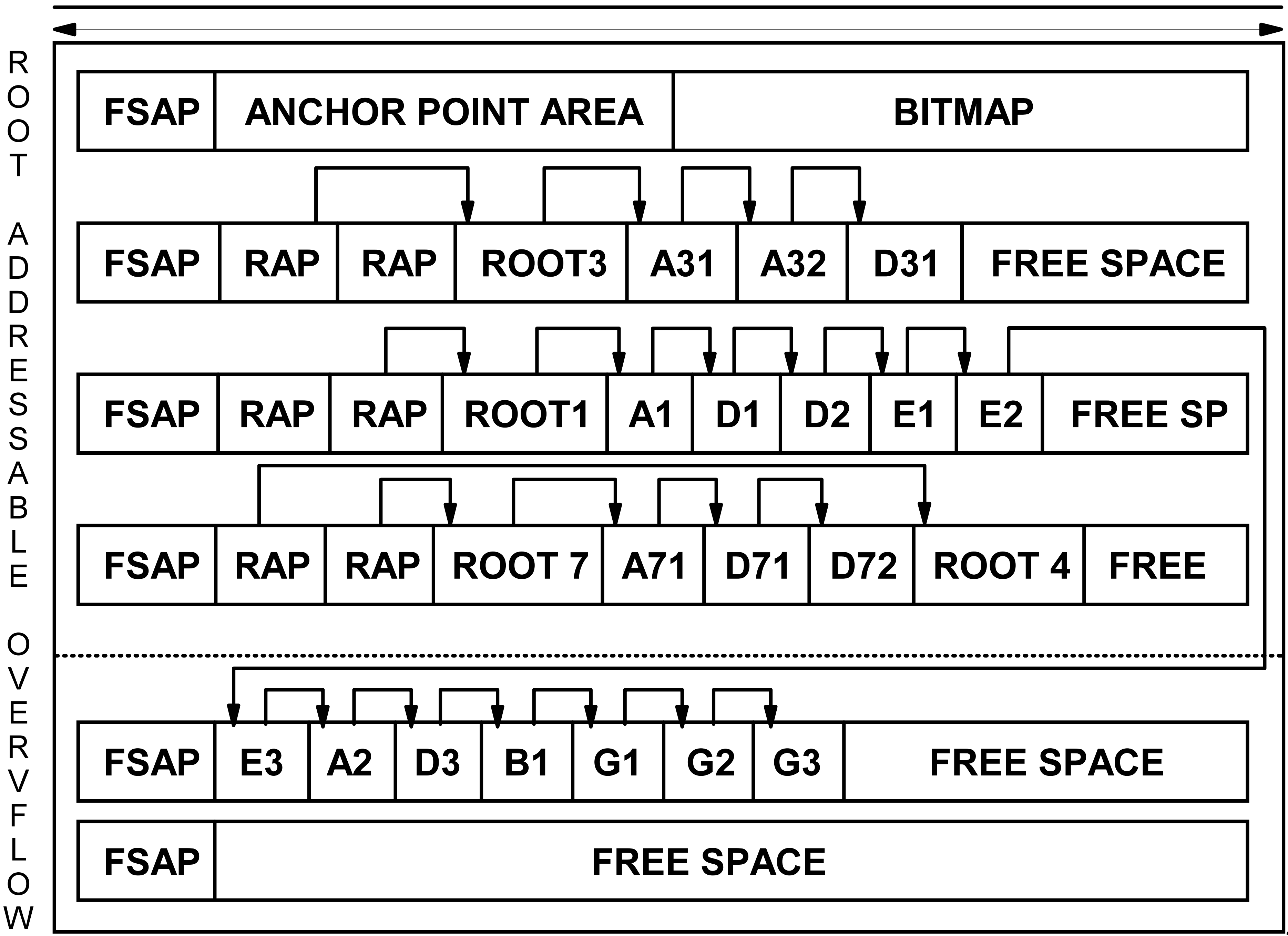
Special HD Fields ...

- Free Space Element

FSE CHAIN	AVAILABLE LENGTH	TASK ID
2	2	4

- First 2 bytes are offset, in bytes, to next FSE
  - Zero if this is the last FSE in the block or CI
- Second 2 bytes are length of free space, including FSE
  - No FSE is created if free space is less than 8 bytes long
- Last 4 bytes is the task ID of the program that freed the space
  - Allows a program to free and reuse the same space without contention
  - Useful in determining who free the space

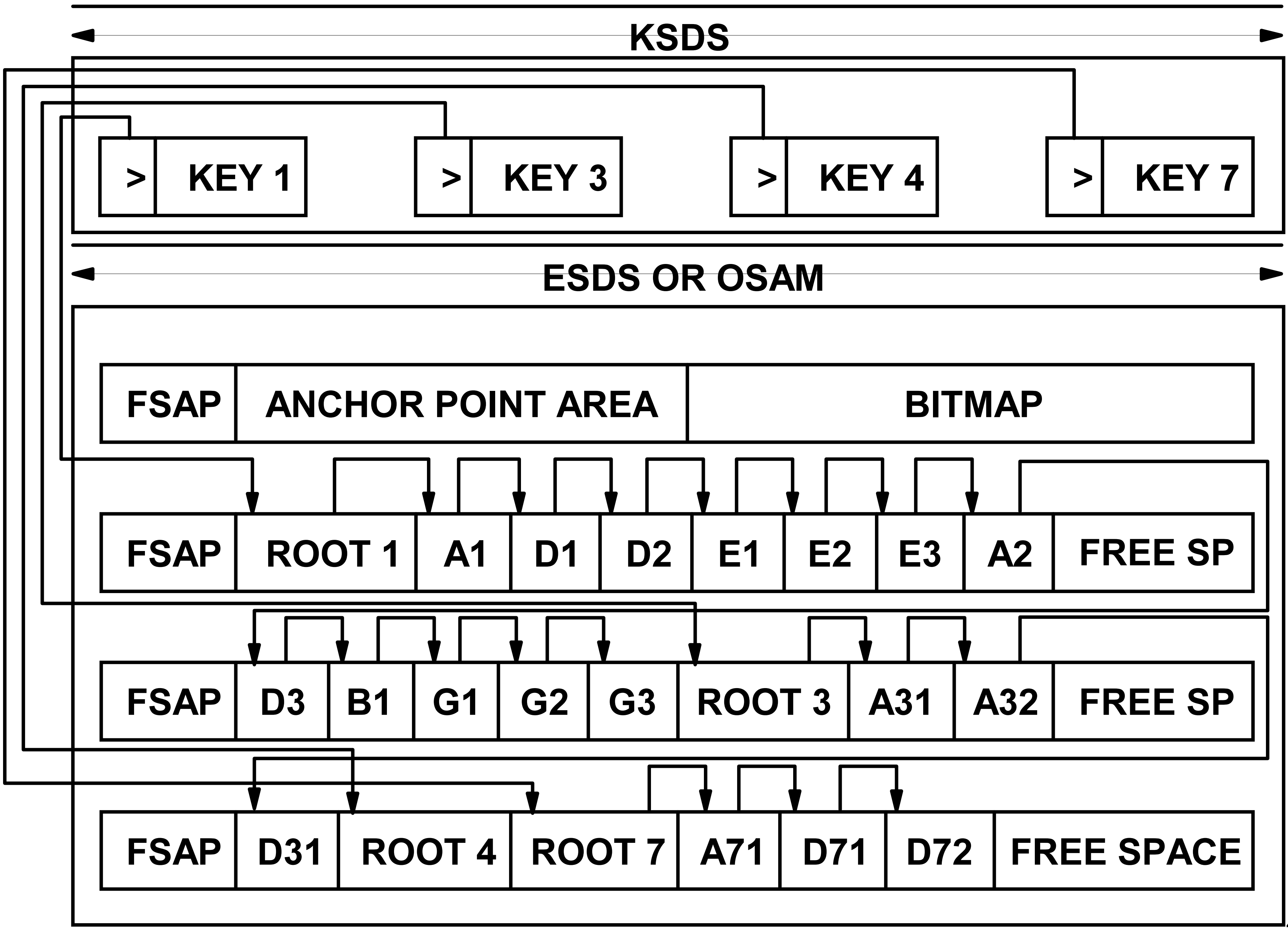
HDAM Storage



HDAM Storage ...

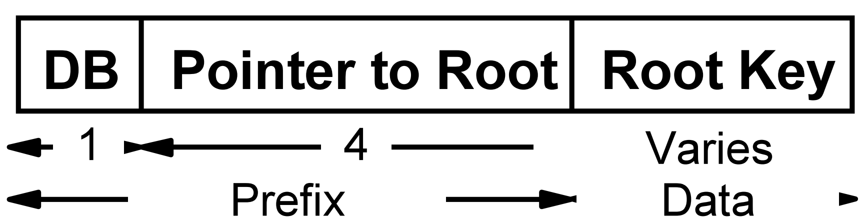
- Root Addressable Area (RAA)
  - Number of blocks or CIs defined in RMNAME parameter
  - Primary storage area for roots and dependents
    - Number of dependents at initial load is limited by RMNAME
    - Insert until specified bytes limit would be exceeded
  - All RAPs are in the RAA
  - Location is determined by Randomizer specified in RMNAME
    - Randomizer input is the root segment's key
    - Randomizer output is a block number and RAP number
    - Keys that randomize to same block and RAP are synonyms
    - Synonyms are chained using PTF pointers
    - Chain is ascending key sequence or by insert rules
- Overflow Area
  - For segments that do not fit in the RAA
  - No RAPs are present in the overflow area

HIDAM Storage



HIDAM Storage ...

- Data Component
  - A VSAM ESDS or OSAM data set
  - No RAA or Overflow portions
  - Database records are stored in key sequence
  - Roots must have unique keys
  - Segments in hierarchic sequence
  - You can specify that free space be left after loading
    - A percentage in each block or CI
    - Every Nth block or CI
- Index Component
  - VSAM KSDS
  - The index is a root-only database
  - One index segment for each database root



HIDAM RAP

- One RAP per block or CI if PTR=T or PTR=H for the root
  - No RAP is generated if PTR=TB or PTR=HB
  - No RAP is generated if PTR=NOTWIN
- Roots are chained from RAP in reverse order of insertion
  - RAP points to most recently inserted root
  - Each root points to previously inserted root
  - First root inserted has a zero pointer
- Index must be used to process roots sequentially
  - Index must also be used if NOTWIN is specified
- Remember that TWIN is the default
  - Specify something useful!
  - Use backward pointers if you process roots sequentially
  - Use NOTWIN if you only do random processing

Processing HD Databases

- Delete
  - The segment and all of its dependents are removed
  - FSE is used indicate the space is free
    - Create a new FSE and update the FSAP/FSE Chain
    - Update length field of preceding FSE
  - Segment points are updated

- Replace
  - No change in length or fixed-length
    - Overwrite old segment with updated segment
  - Shorter segment
    - Space previously occupied is freed
    - FSE created if at least 8 bytes shorters
  - Longer segment
    - If adjacent free space lets it fit, store in original location
    - If no space available, separated data

      Data part goes to overflow with prefix of SC and DB=x'FF'

      Bit 4 of DB in original prefix is turned on

      Pointer to data in overflow is built after prefix

      Remainder of space is freed

Processing HD Databases ...

- Insert
  - Store in the Most Desirable Block (MDB)
    - HDAM root MDB

      The one which is selected by the randomizer

      The one containing its previous synonym
    - HIDAM root MDB

      If no backward pointer, same as the next higher key root

      If backward pointer, same as the next lower key root
    - Dependents

      If Physical, same as parent or previous twin

      If Hierarchic, same as previous segment in hierarchy
  - Second most desirable block
    - Nth Block or CI left free during loading

      If in buffer pool or bitmap shows space available
    - Specified by FRSPC parameter

      If not specified, then no second MDB

HD Space Search Algorithm

1. **In the MDB (this will be in the buffer pool)**
2. **In the second MDB**
3. **Any block in the buffer pool on the same cylinder**
4. **Any block on the same track**
   - **If the bitmap shows space available**
5. **Any block on the same cylinder**
   - **If the bitmap shows space available**
6. **Any block in the buffer pool within +/- SCAN cylinders**
7. **Any block within +/- SCAN cylinders**
   - **If the bitmap shows space available**
8. **Any block at the end of the data set is in the pool**
9. **Any block at the end of the data set**
   - **If the bitmap shows space available**
   - **Extend the data set if necessary**
10. **Any block where the bitmap shows space**

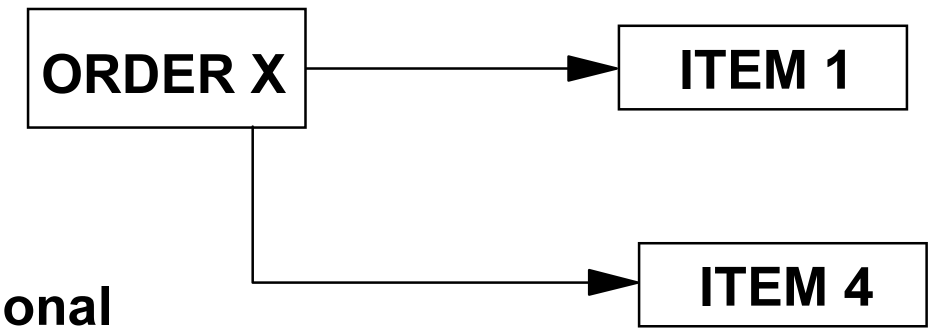
Logical Relations

TOPIC

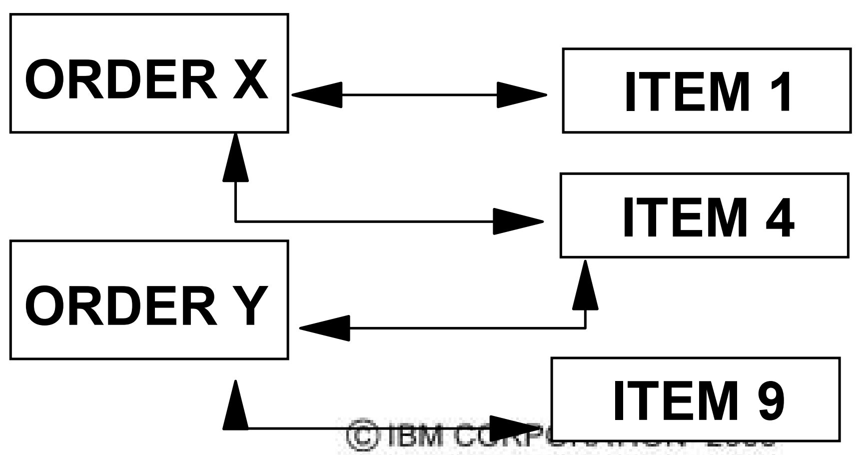
Logical Relations

Types

- Unidirectional
  - A one-way relationship from one database record to another
  - Applications always start from one place

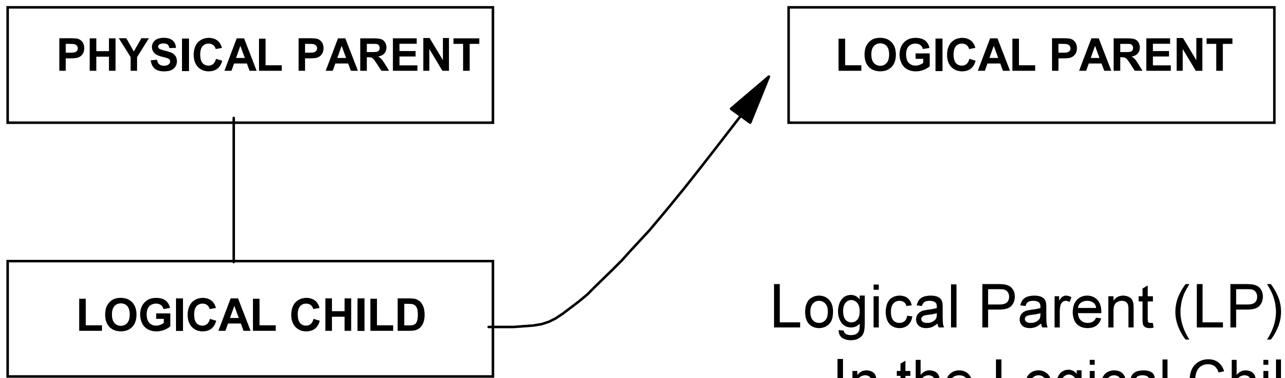


- **Bidirectional**
  - **A two-way relationship between database records**
  - **Applications may need to start on either side**
  - **IMS maintains both sides of bidirectional relationships**



How Logical Relationships are Implemented

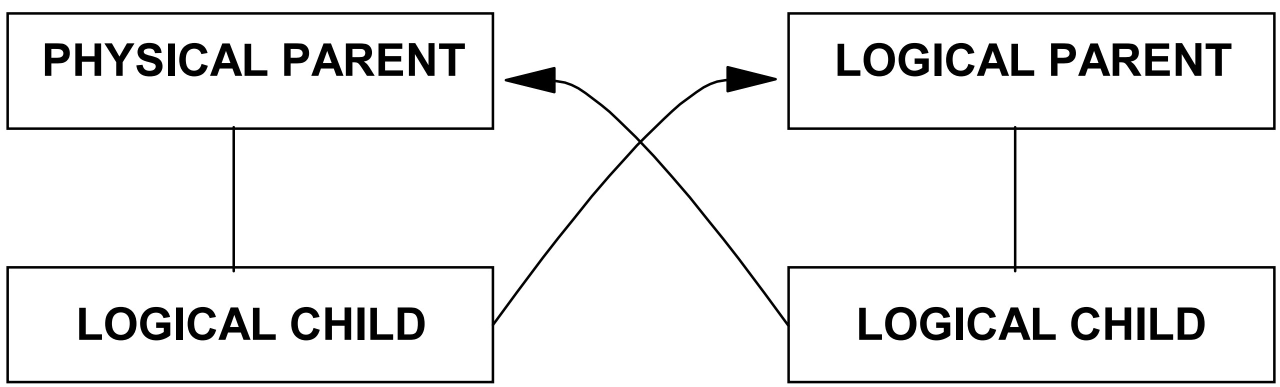
Unidirectional



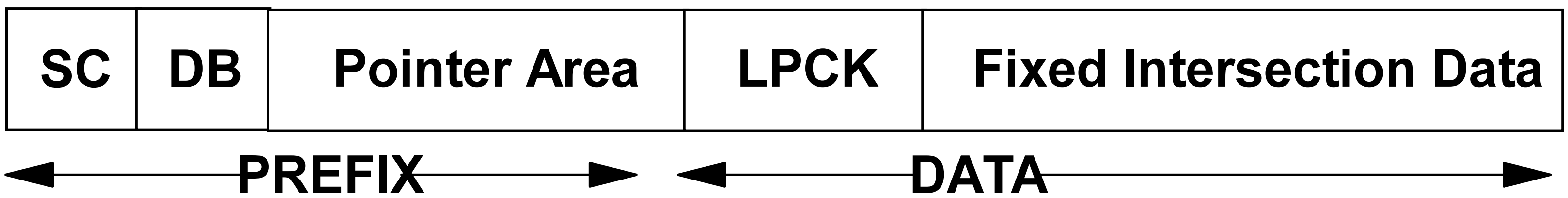
Logical Parent (LP) Pointer

In the Logical Child segment points to logical parent

Bidirectional



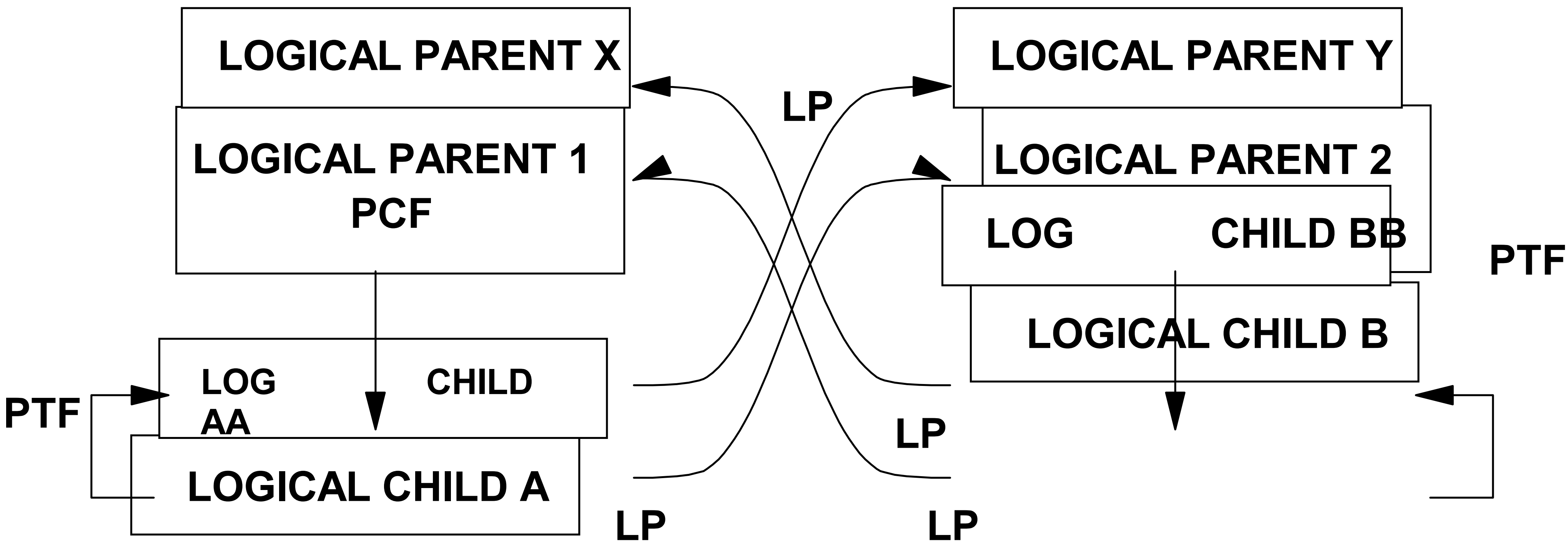
The Logical Child



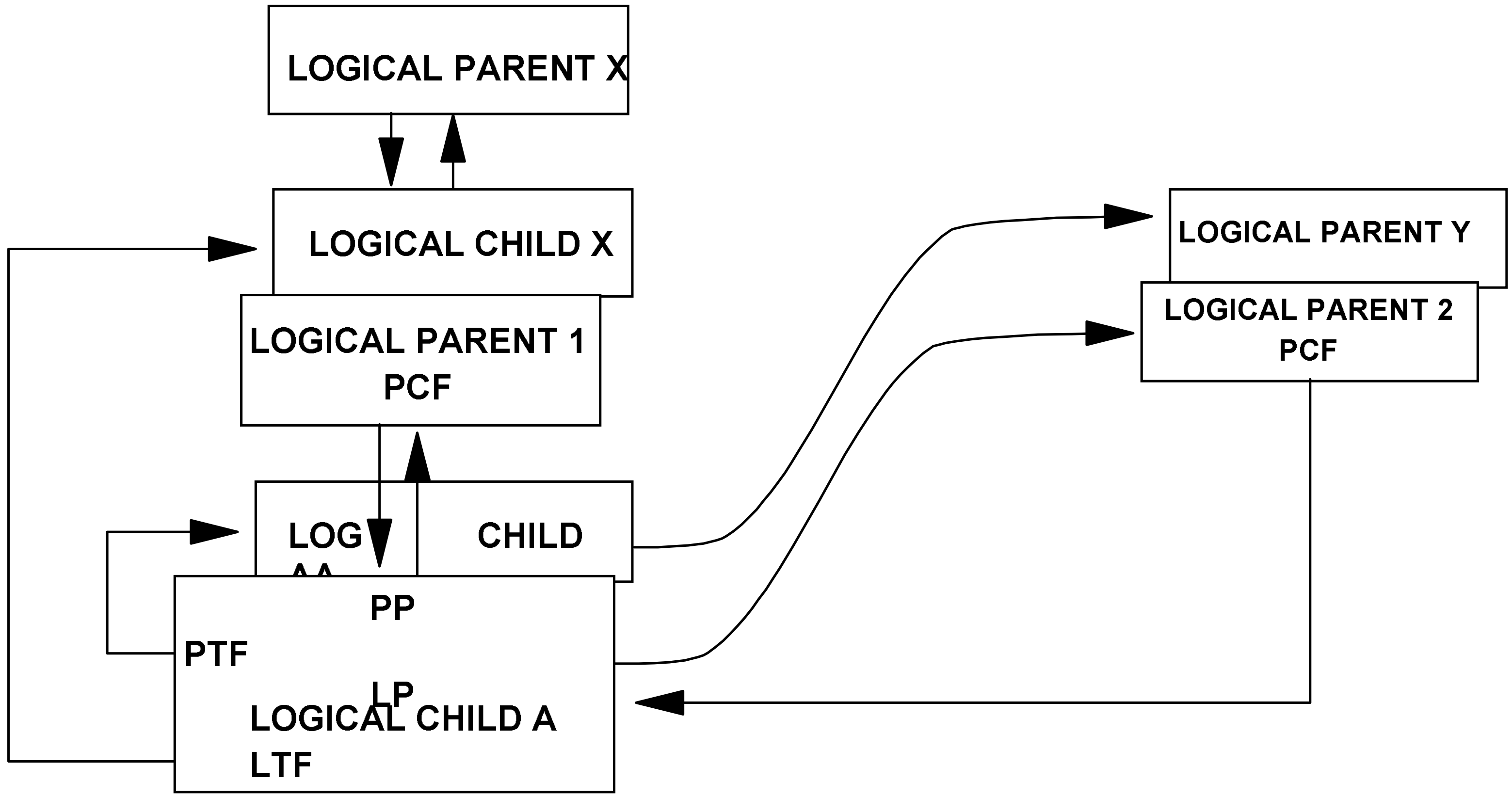
- Logical Parent Concatenated Key
  - Sequence fields of all segments from root to logical parent
  - Always appears to the application program
  - May or may not be physically stored with logical child
    - If not stored, IMS generates it on retrieval
- Logical Parent Pointer
  - The LPCK if it is physically stored
    - Must be used if logical parent database is HISAM
    - This is called a symbolic pointer
  - A 4-byte pointer in the segment prefix
    - May only be used if logical parent database is HD
    - The only kind of pointer that can exist in HISAM
- Fixed Intersection Data
  - Data that is dependent on the logical relation
  - Maintained on both sides of a bidirectional relation
  - Variable intersection data is in dependents of the logical child

Bidirectional Physical Pairing

Physical or Hierarchic relate Physical Parent and Logical Children
Logical Parent relates Logical Child to Logical Parent
Requires a physical segment on both sides of the relation



Bidirectional Virtual Pairing



- Logical Child First (LCF) replaces PCF
- Logical Twin Forward (LTF) replaces PTF
- Physical Parent (PP) replaces (LP)
- Physical segment only exists on one side of relation
- Real Logical Child must be in HD database

Logical Relation Prefix

- Logical Child Prefix
  - PP, LTF and LTB only present if virtual pairing

SC	DB	HF	HB	PP	LTF	LTB	LP

OR

SC	DB	PTF	PTB	PP	LTF	LTB	LP	PCF	PCL

- Logical Parent Prefix
  - PP only if a lower level segment is a logical parent

SC	DB	HF	HB	PP	LCF	LCL

SC	DB	PTF	PTB	PP	PCF	PCL	LCF	LCL

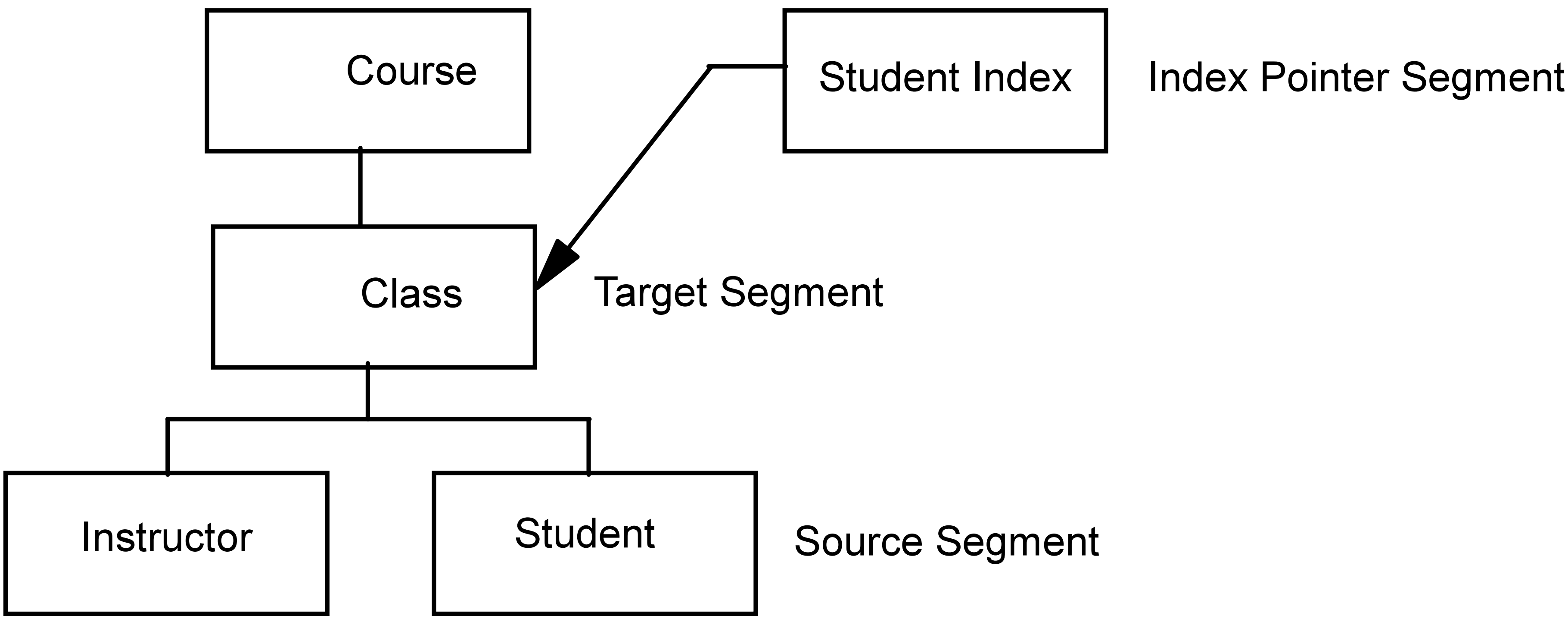
Secondary Indices

TOPIC

Secondary Indices

Why Secondary Indices

- **Processing sequence other than root key**
  - **Avoid scan for non-key field**
- **Direct access to lower level segments**
  - **Faster processing**



Secondary Index (SI)

- Can be based on HISAM, HDAM, or HIDAM
- Is a separate database
  - Can be processed on its own
- Uses fields from the source segment to create a key
- Access via a secondary index is to the target segment
- Invisible to the application
  - PROCSEQ = on PCB tells IMS to use the secondary index
  - Application must use XDFLD name in the SSA
- Limits on secondary indices
  - 32 secondary indices onone segment type
  - 1000 secondary indices for a database
- Secondary index is a special kind of logical relation

RETURN TO INDEX

Fields in the Index Pointer

DB	Pointer	Constant optional	Search	Subsequenc e optional	Duplicate Data optional	Concat Key opt HD	User opt
◄—1—►	◄—4—►	◄—1—►	◄———	———	Variable	———	———►

- Pointer is used when target is in HD database
- Constant is used for shared secondary indices
  - More than one SI in the same database
- Search is made up of up to 5 fields form the source
  - This is the key of the secondary index
- Subsequence is up to 5 fields from source or IMS-generated values
  - Used to make the secondary index key unique
- Duplicate Data is up to 5 fields from the source
  - Only used when processing the SI as a database
- Concatenated Key is the symbolic pointer to the target
  - Required when the target is in HISAM database
- User Data is anything you want to stick in there
  - Only used when processing the SI as a database