E03

A Beginner's Guide to IMS Databases

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Conference Note

- If your particular interest is in HALDB databases, you may wish to consider the following sessions...
  - E11 - Introduction to HALDB Wednesday 1:15 PM Vern Watts
  - E30 - Application Design... Tuesday 8:30 AM Rich Lewis
  - E81 - Migrating to HALDB Monday 2:15 PM Rich Lewis

Database Basics

TOPIC

Database Basics

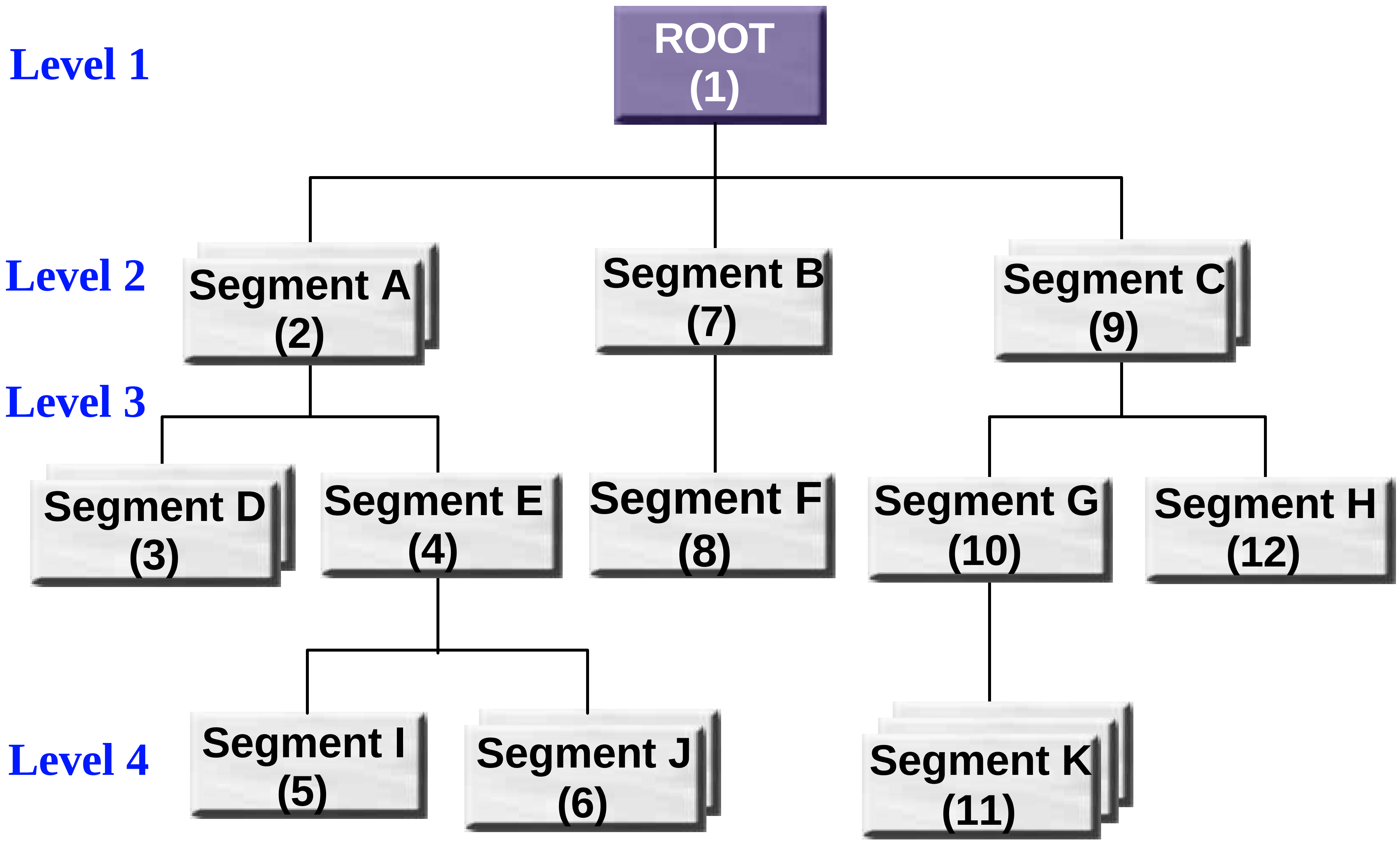
What is a Database

- 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 segment 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 parent
- 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

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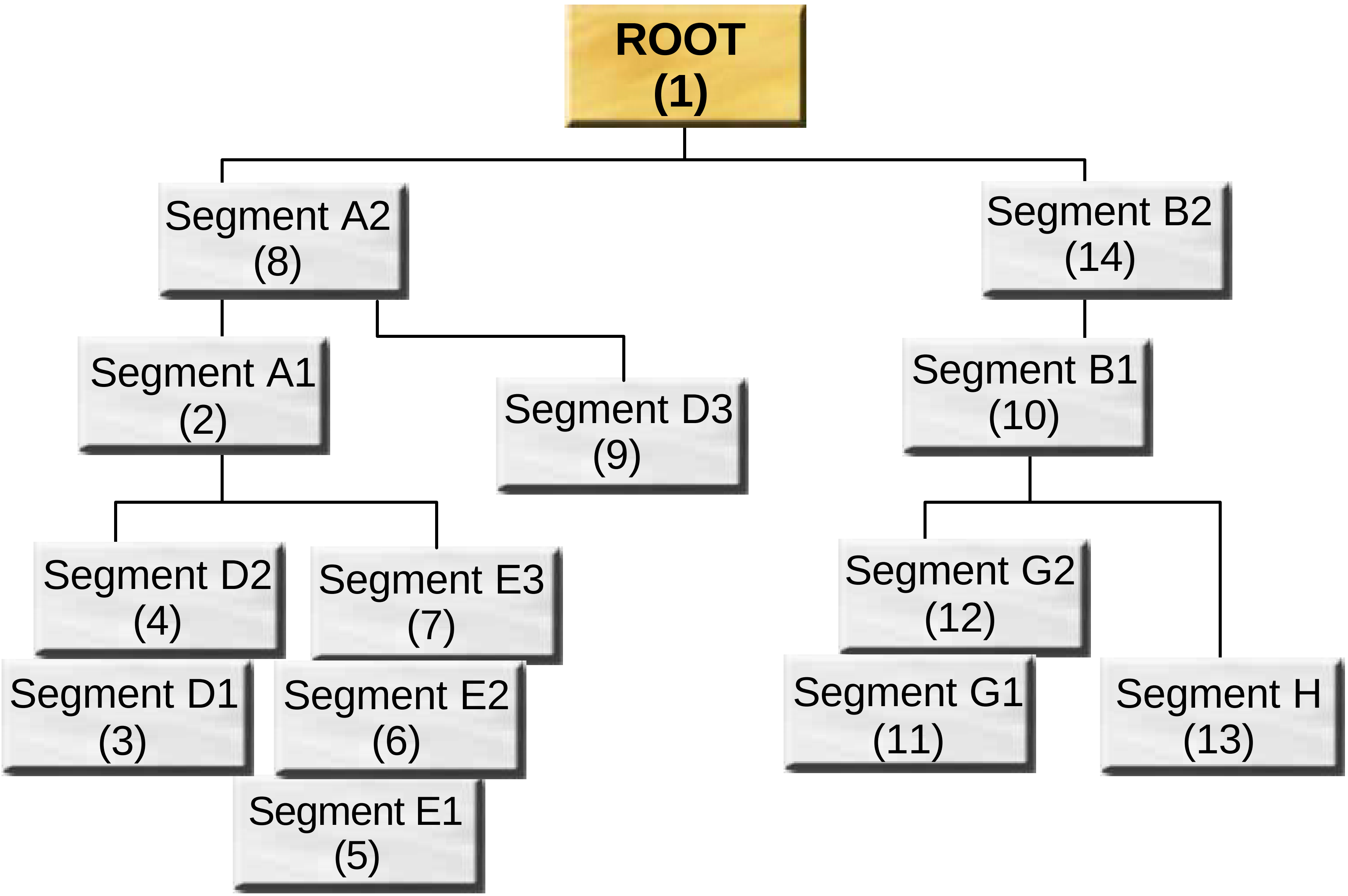
Hierarchic Sequence

- 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

IBM

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

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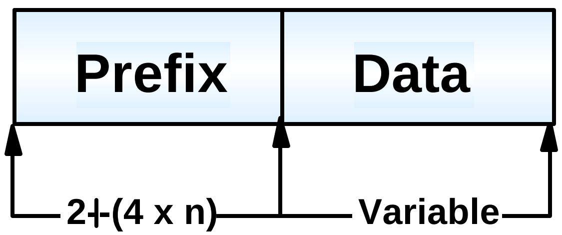
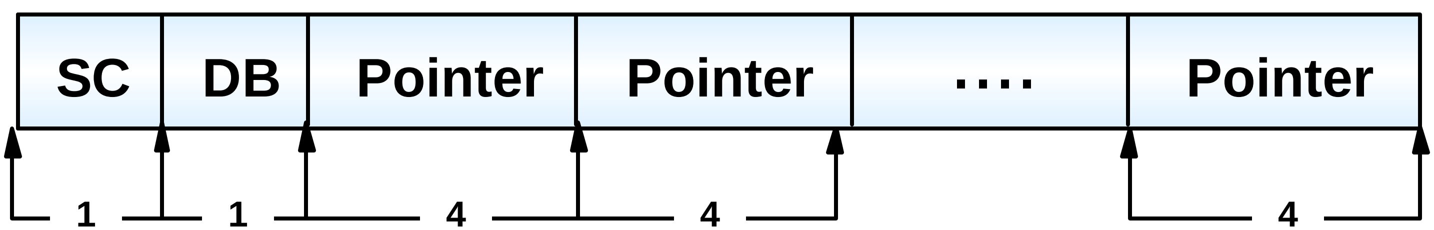
Segments in Storage

- 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

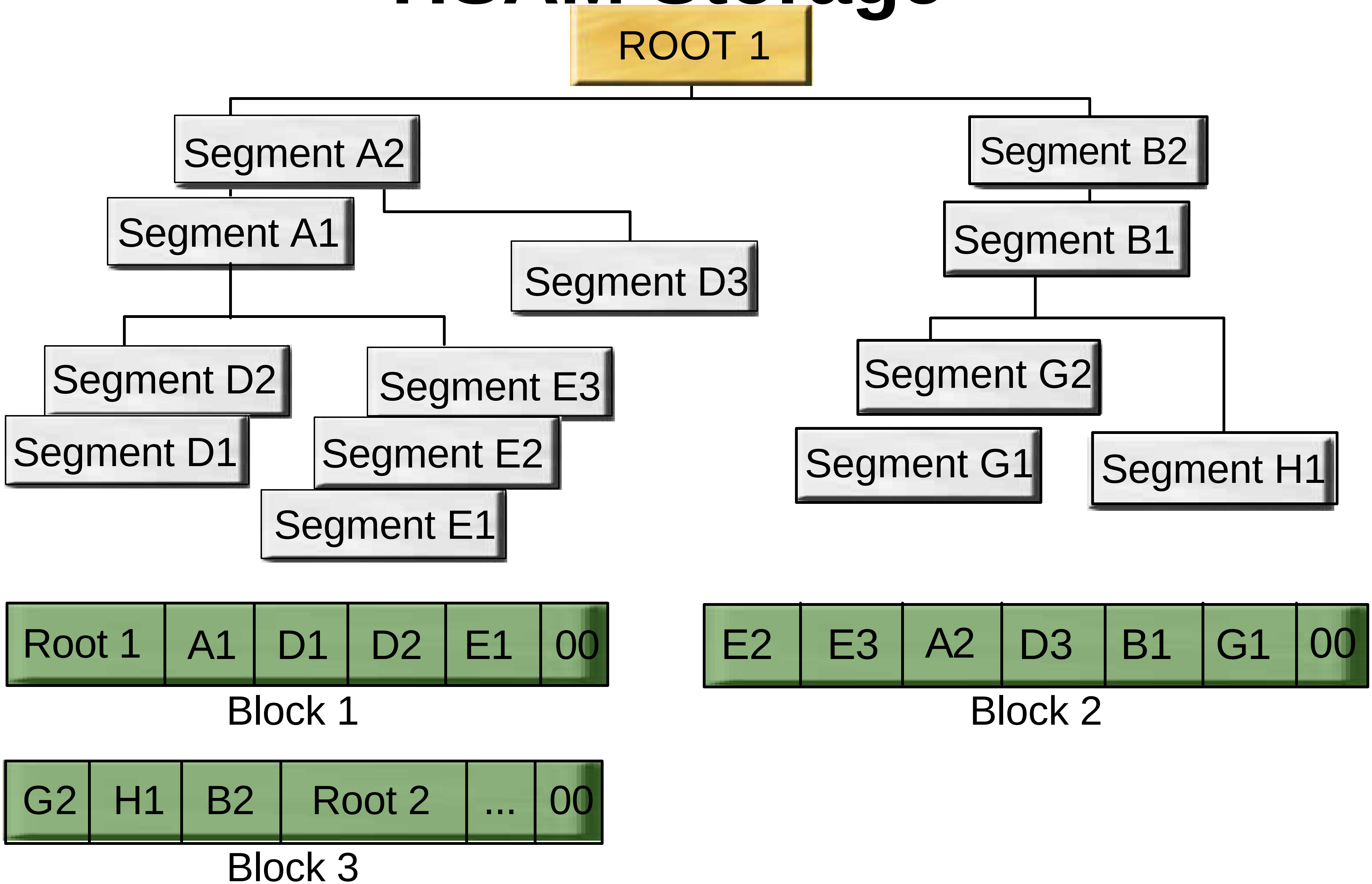
Sequential Organization

- 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
  - Hierarchical Sequential Access Method (HSAM)
  - Simple Hierarchical Sequential Access Method (SHSAM)
    - Root-only HSAM
  - Hierarchical Indexed Sequential Access Method (HISAM)
  - Simple Hierarchic Indexed Sequential Access Method (SHISAM)
    - Root-only HISAM using VSAM
  - Generalized Sequential Access Method (GSAM)
    - No hierarchy, no database records, no segments

HSAM

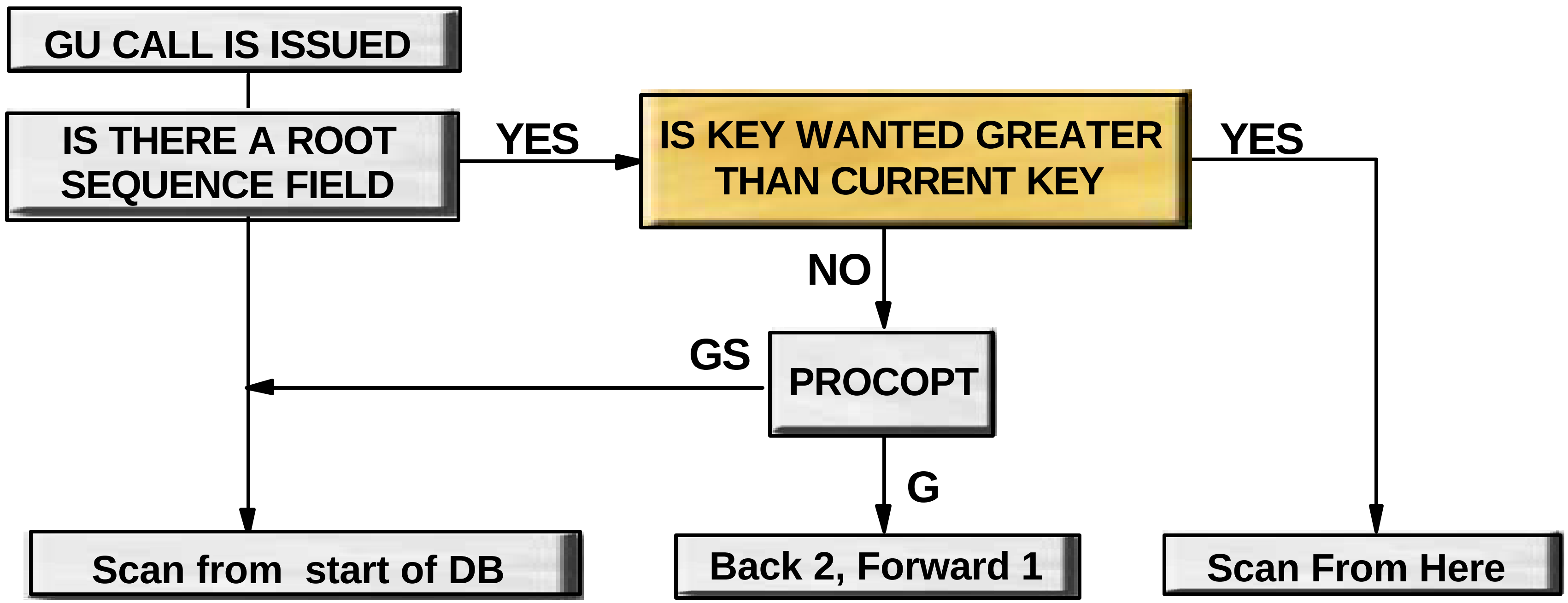
- Tape or DASD
- BSAM or QSAM
  - QSAM if online or PROCOPT=GS (HSAM Only - Get in Ascending Sequence)
- Fixed-Length, Unblocked format
  - RECFM=F, logical record length=physical block size
- Cannot Delete or Replace
  - Update by rewriting the database
  - Insert allowed when loading the database
- 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

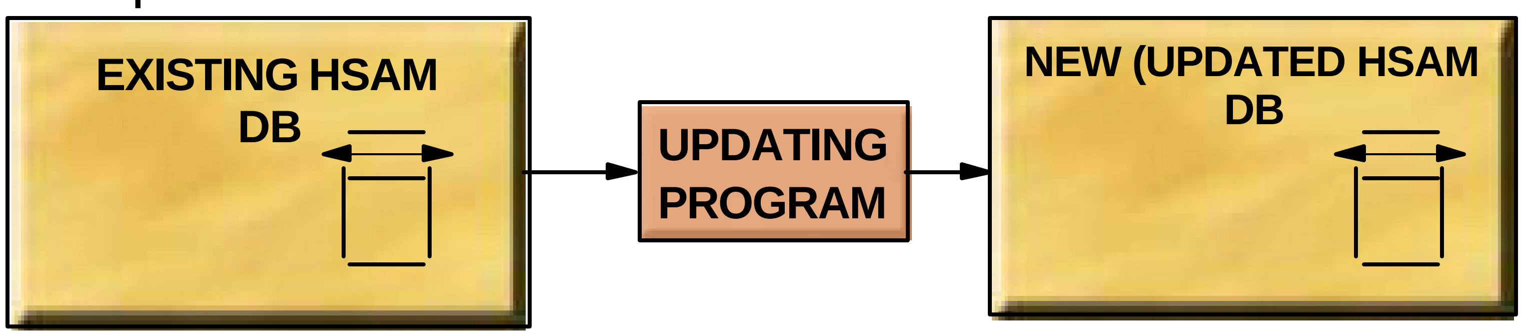


HSAM Processing

- Retrieval



- Update



SHSAM

- HSAM with only one segment type (root-only)
  - No prefix is used
    - No SC because only one segment type
- Same restrictions and processing as HSAM
- Fully equivalent to plain QSAM or BSAM file
  - Communication with non-IMS systems
  - Passing large amounts of data

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HISAM

- DASD only
- VSAM
  - KSDS for the primary data set
  - ESDS 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 Segment Code (SC) and Delete Byte (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

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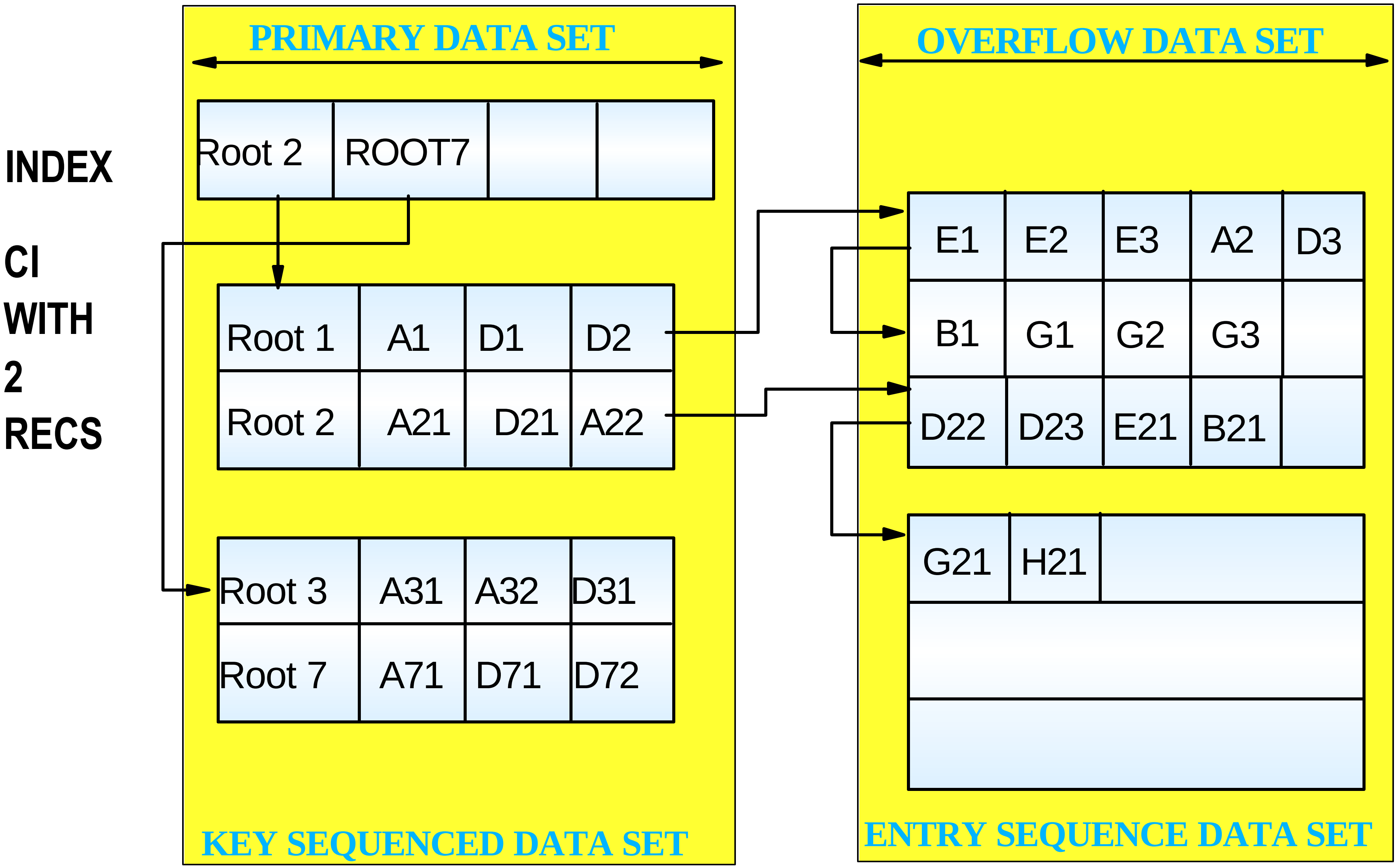
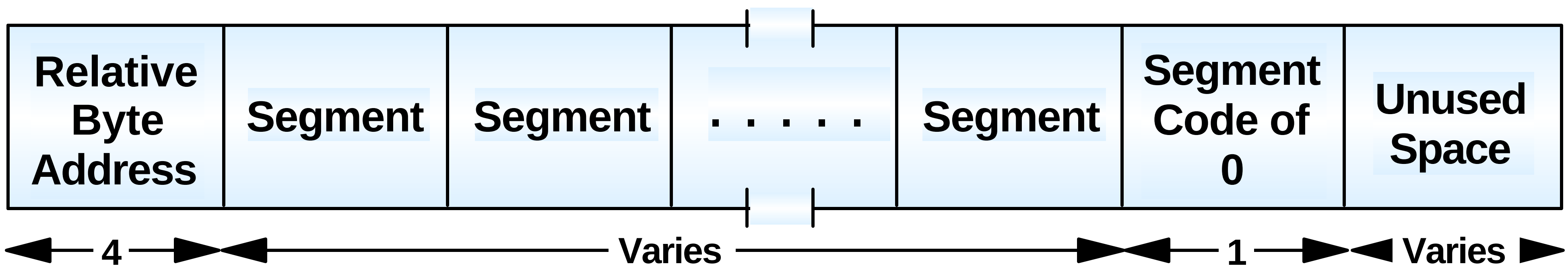
HISAM Storage



HISAM VSAM Logical Record

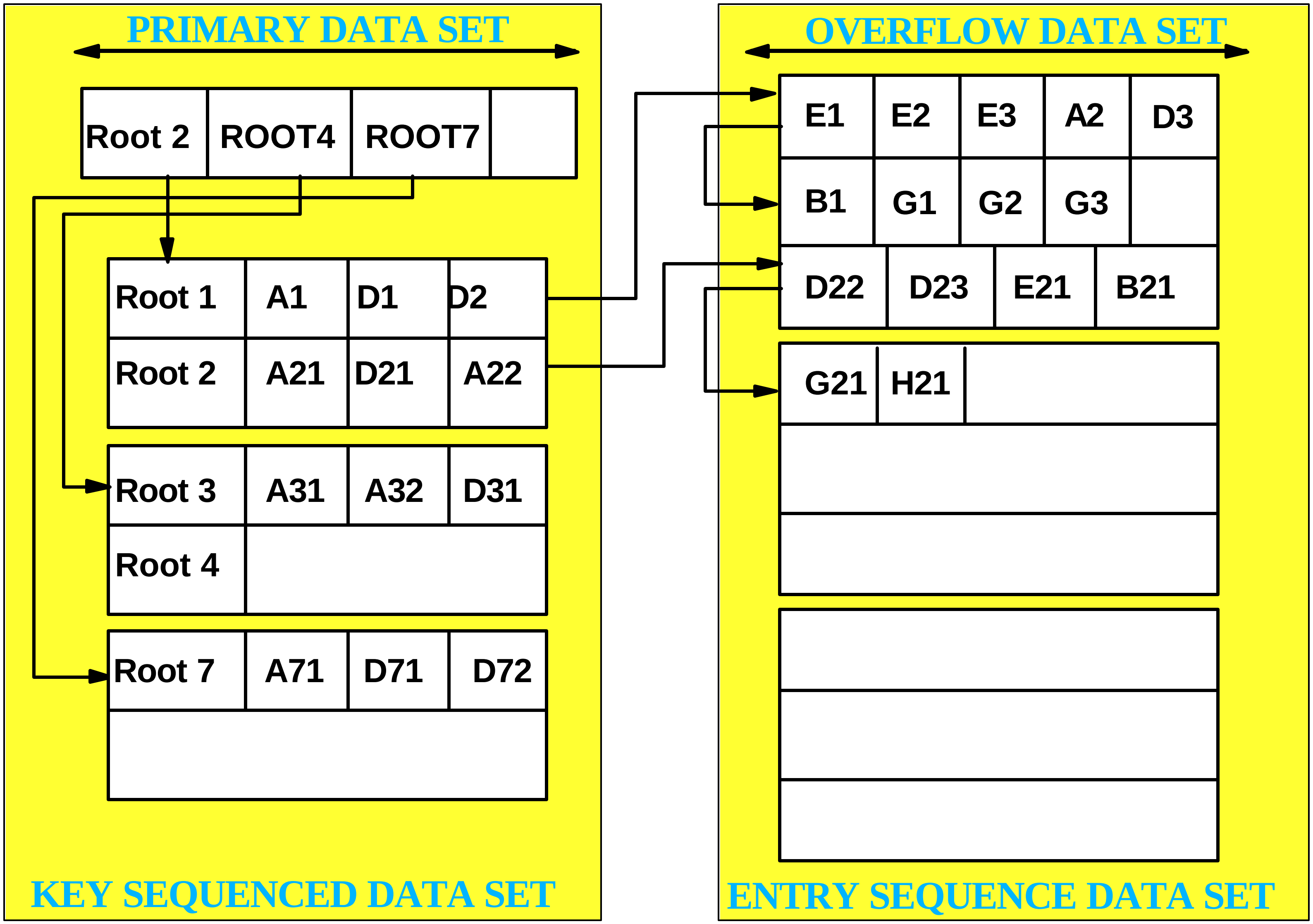


- RBA pointer to the next logical record for this database record
- Last logical record for DB record has zeros
- Segments are stored in hierarchic sequence
- SC of zero indicates end of segments in this logical record
- Unused space can have any data in it

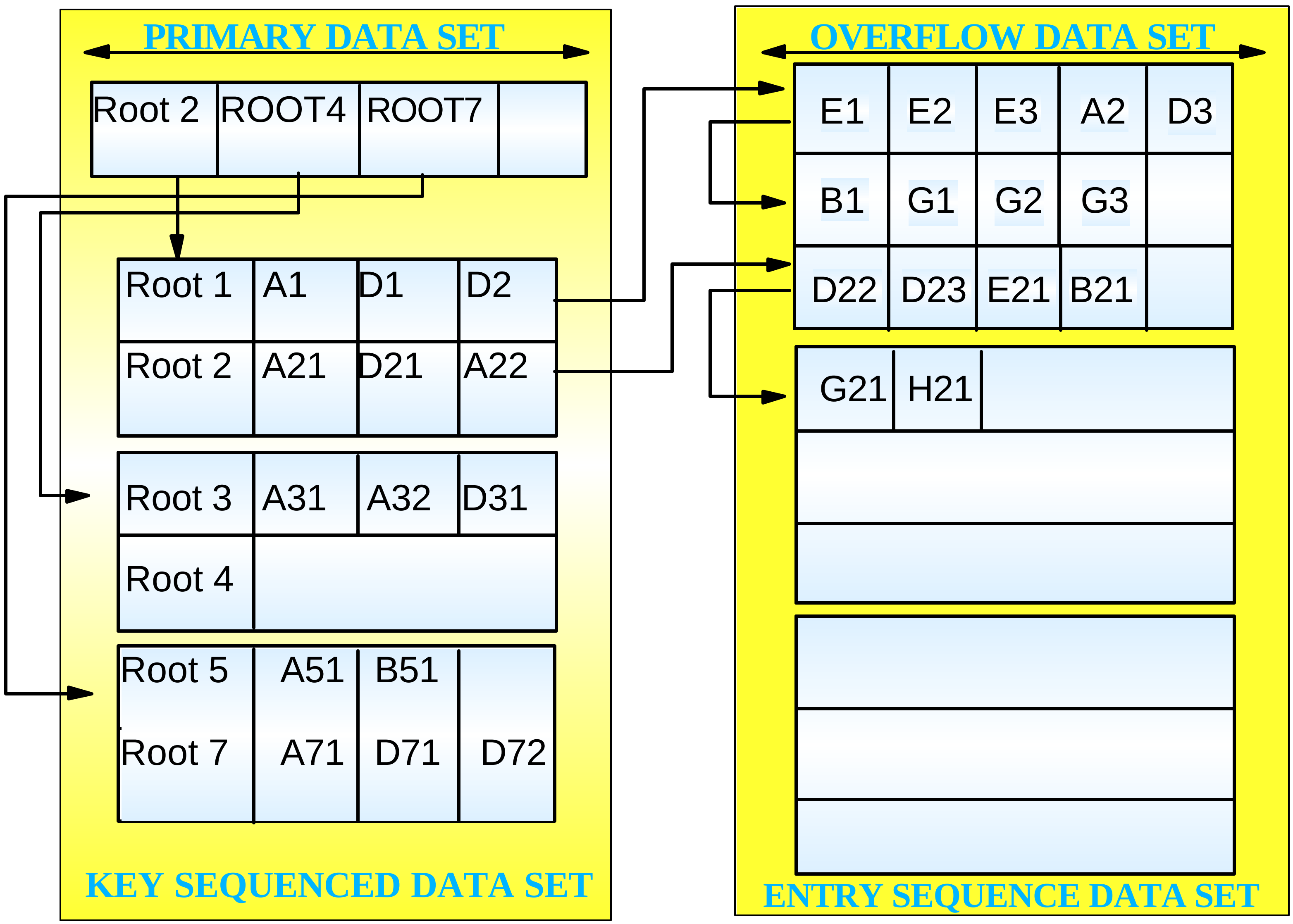
HISAM Inserts

- 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

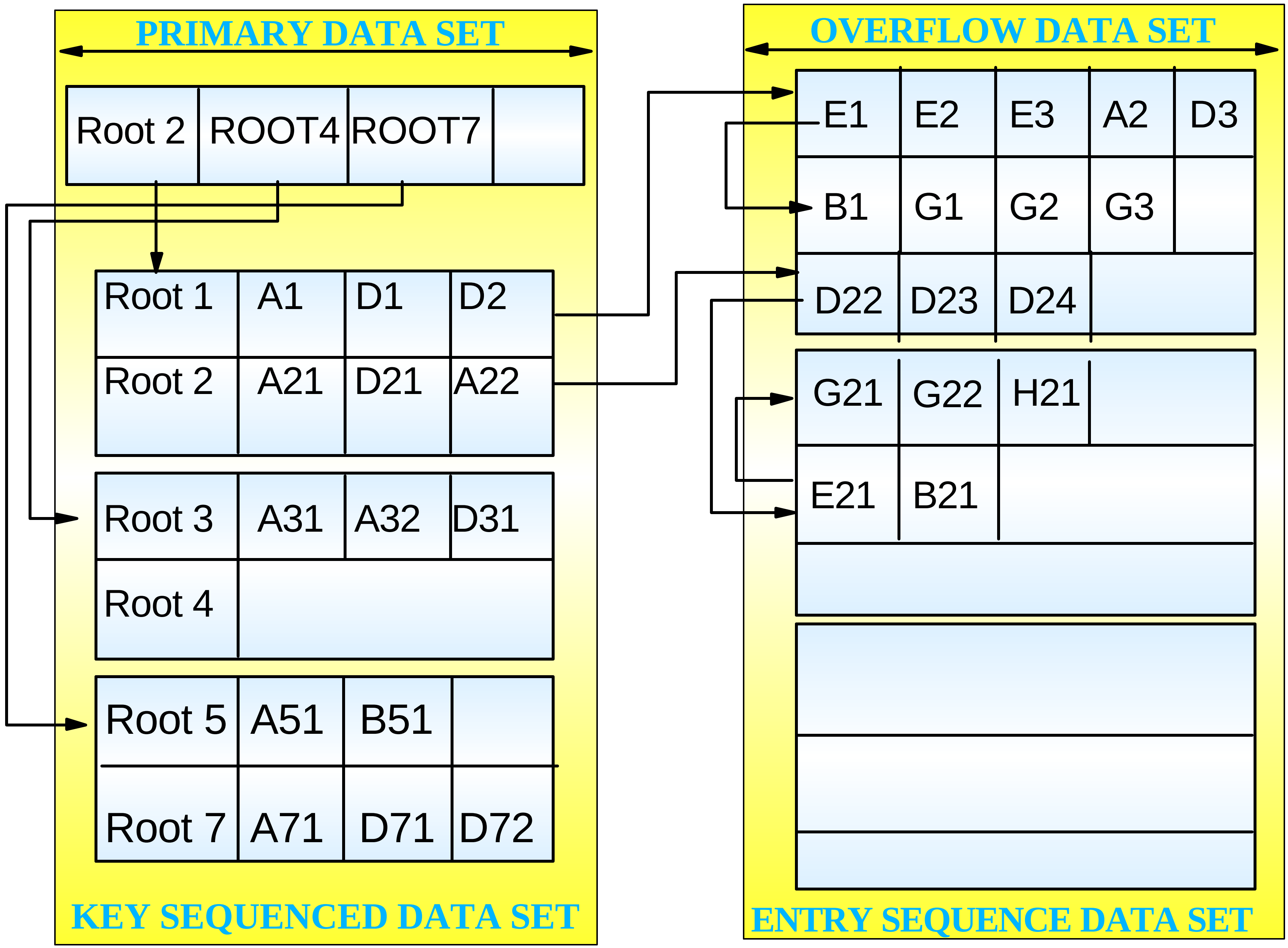
Insert Root 4



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 (parent segment marked)
  - 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 (VSAM erase)
- 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

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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
- High Availability Large Database (HALDB)
  - HDAM and HIDAM databases partitioned using the HALDB Partition Definition Utility (DSPXPDDU) become
    - Partitioned Hierarchic Direct Access Method (PHDAM)
    - Partitioned Hierarchic Indexed Direct Access Method (PHIDAM)
    - See manuals for further information.

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

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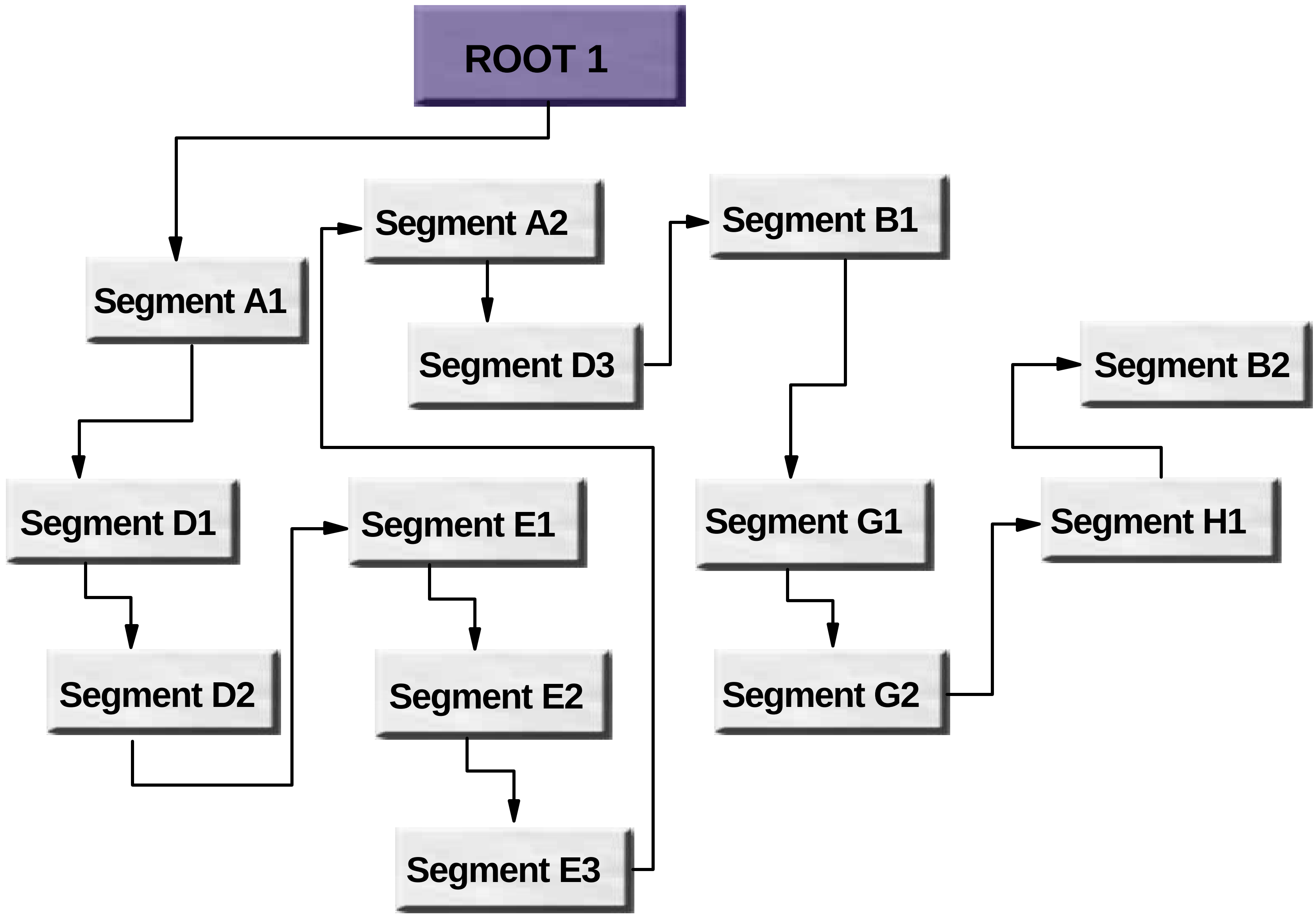
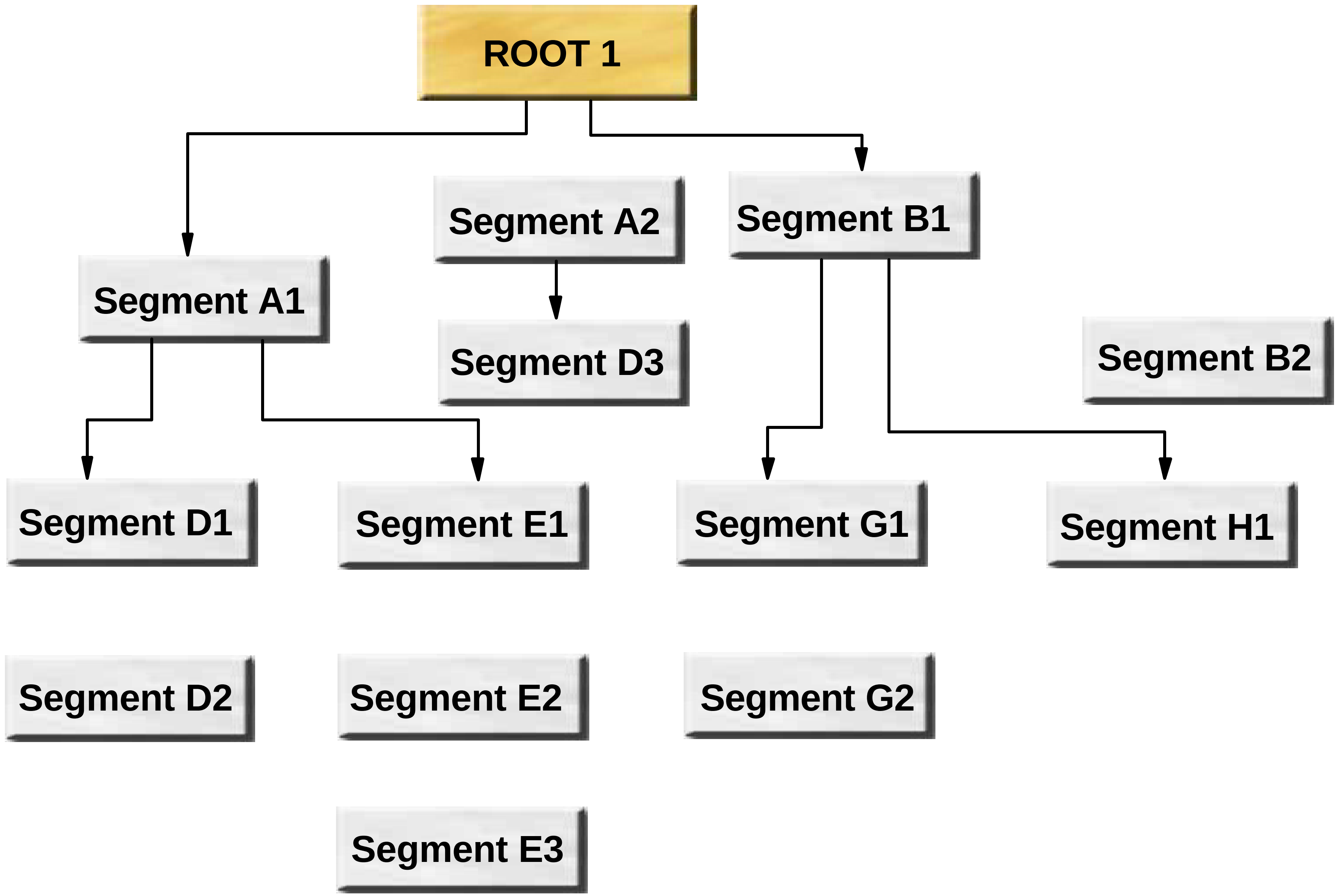
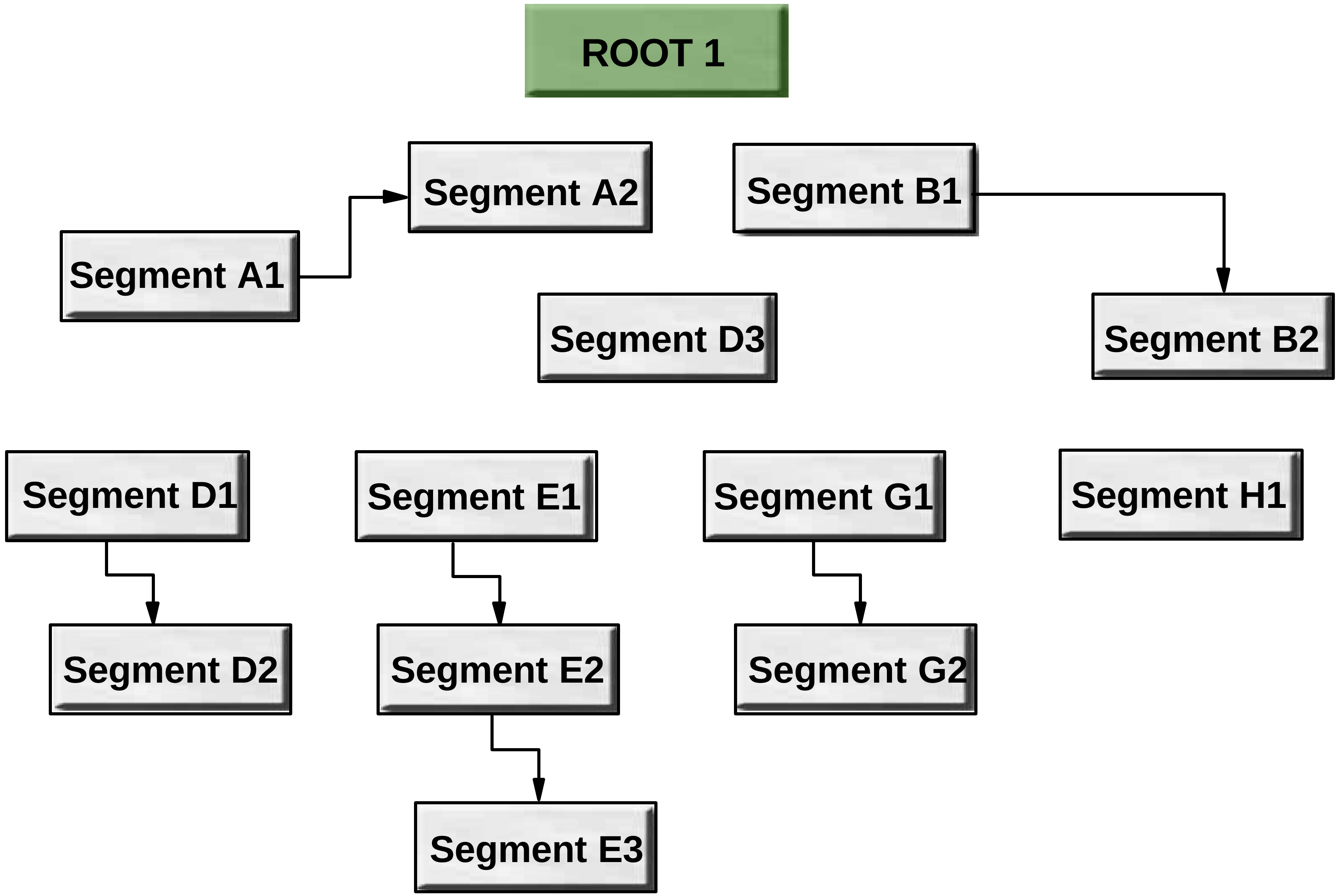
Hierarchic Forward Pointers



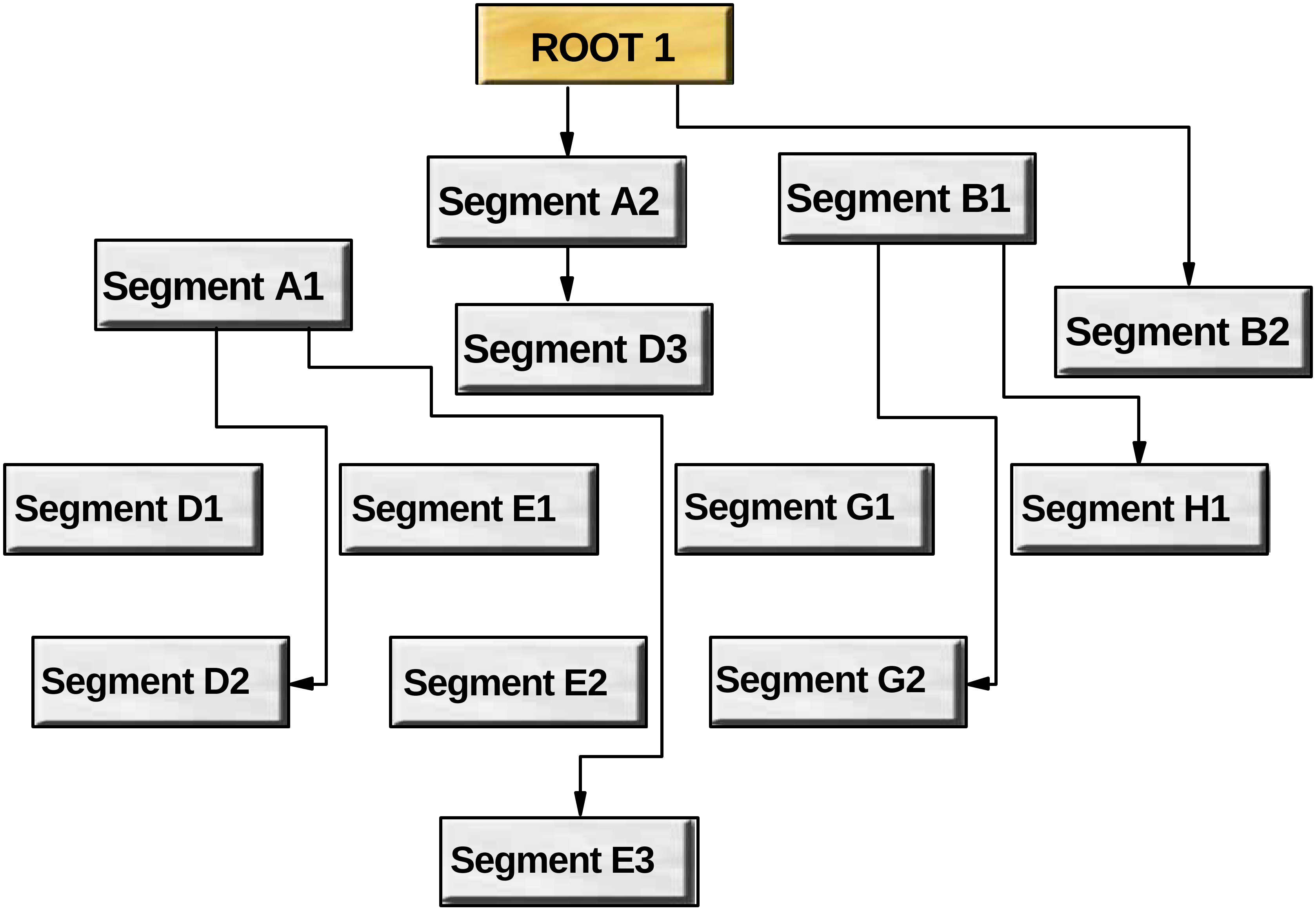
Physical Child First Pointers



Physical Twin Pointers



Physical Child Last Pointers



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

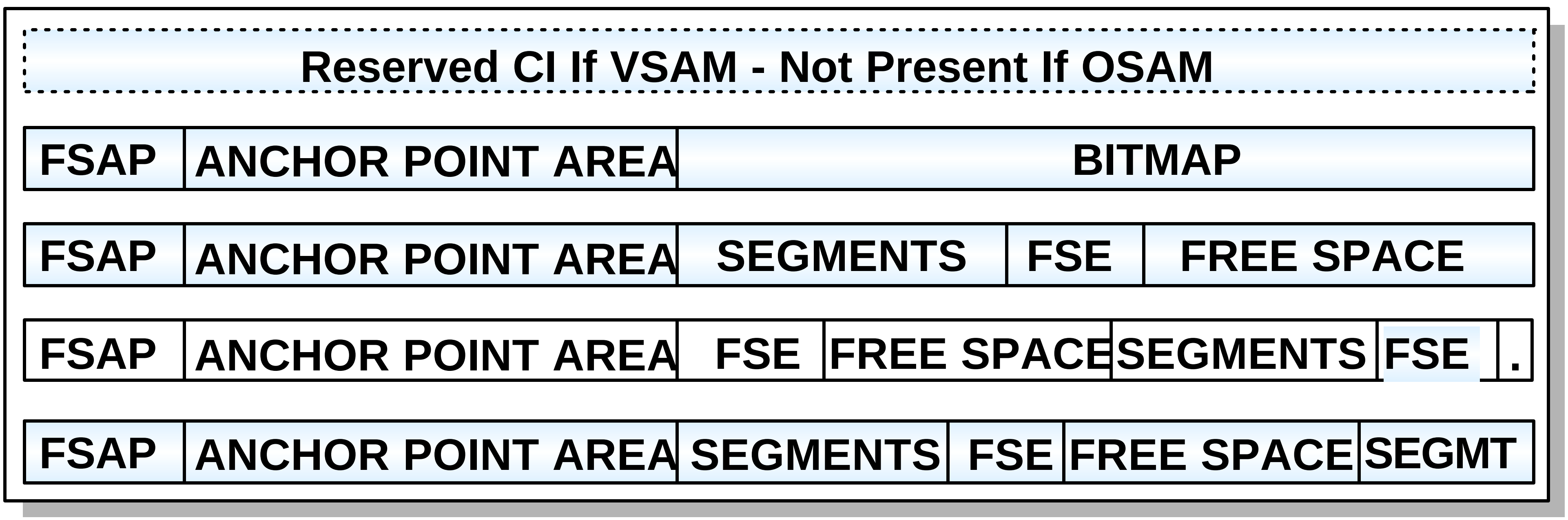
HF	HB	or	PTF	PTB	PCF	PCL

- 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

VSAM ESDS OR OSAM DATA SET

- 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

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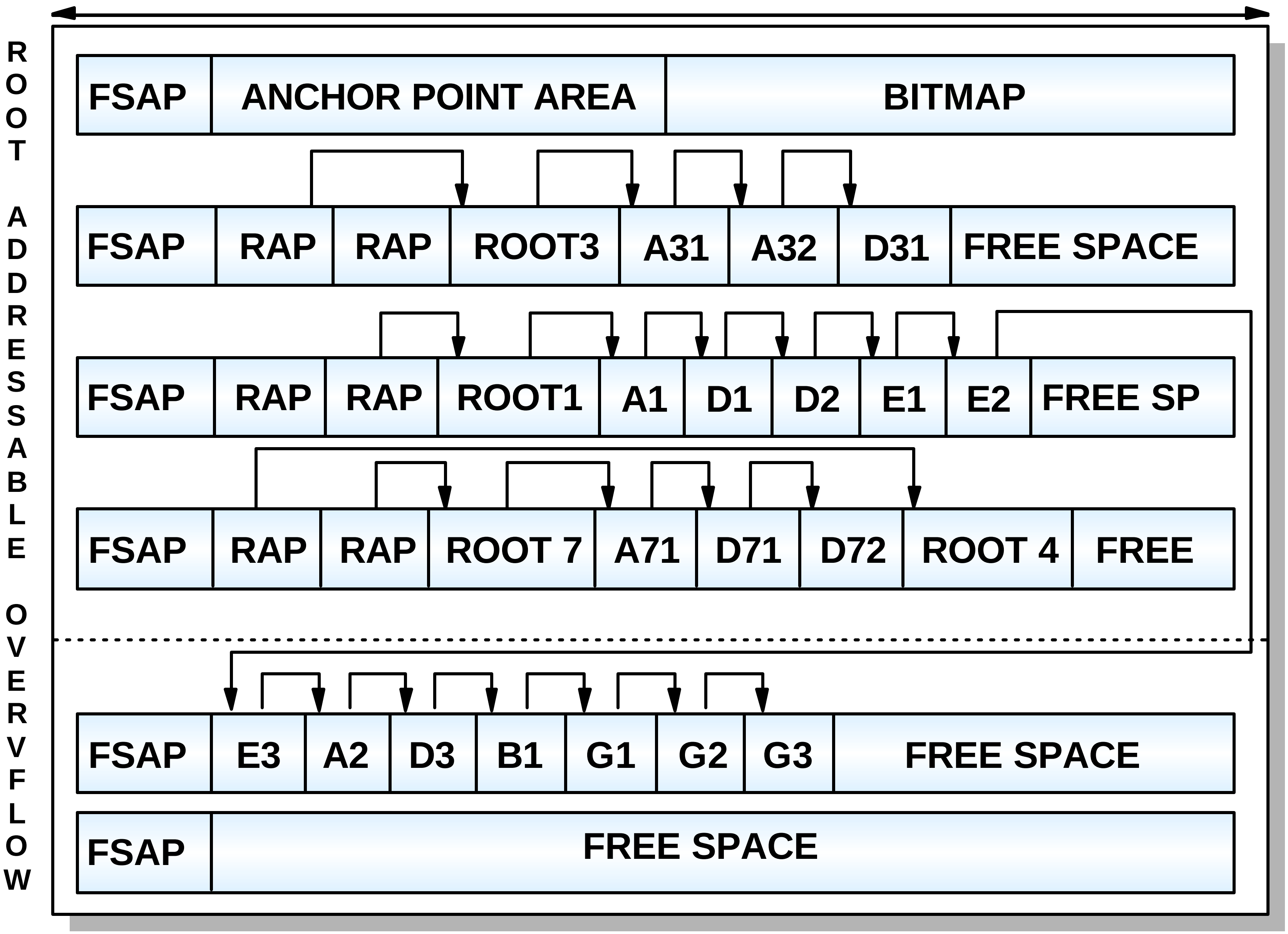
Special HD Fields ...

- Free Space Element

  - 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 freed 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

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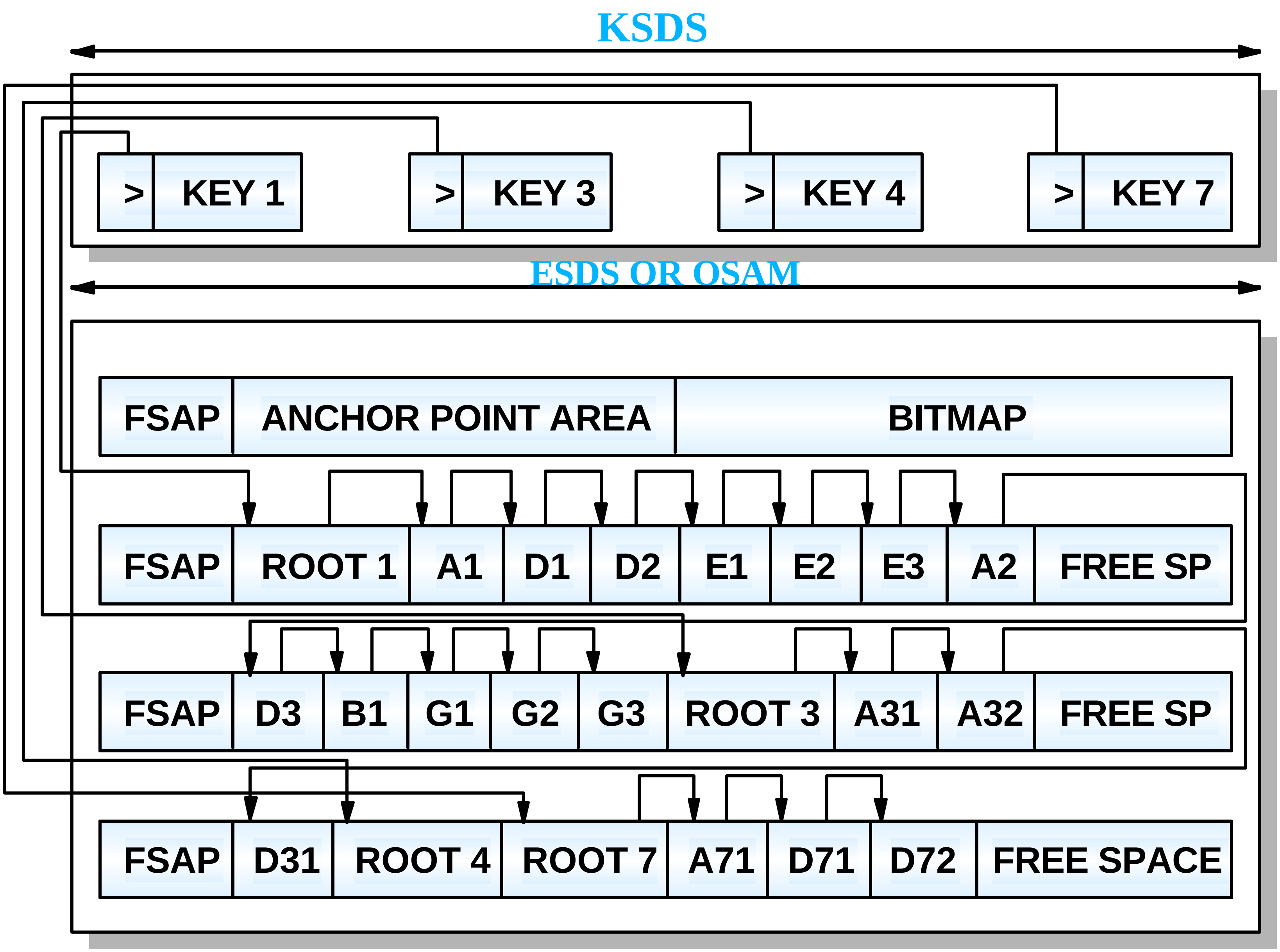
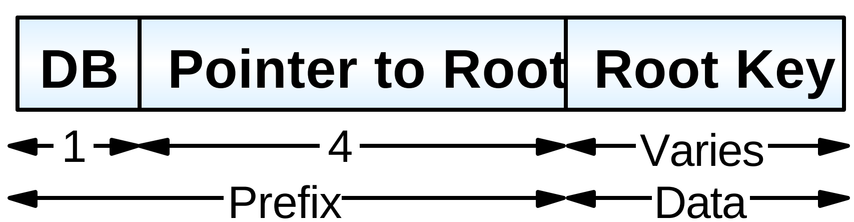
HIDAM Storage



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
  - Pointers 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 shorter
  - 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

IBM

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

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HD Space Search Algorithm

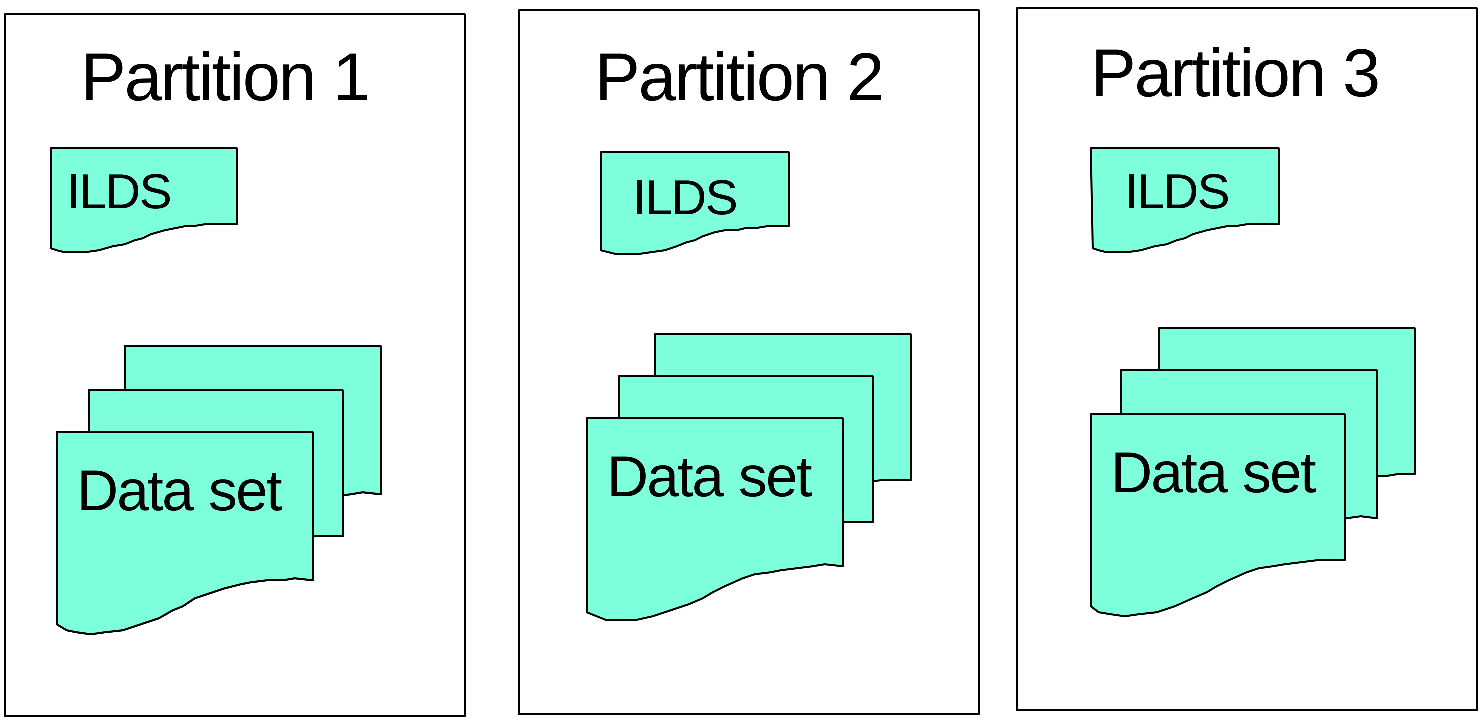
- In the MDB (this will be in the buffer pool)
- In the second MDB
- Any block in the buffer pool on the same cylinder
- Any block on the same track
  - If the bitmap shows space available
- Any block on the same cylinder
  - If the bitmap shows space available
- Any block in the buffer pool within +/- SCAN cylinders
- Any block within +/- SCAN cylinders
  - If the bitmap shows space available
- Any block at the end of the data set is in the pool
- Any block at the end of the data set
  - If the bitmap shows space available
  - Extend the data set if necessary
- Any block where the bitmap shows space

A Quick Look at HALDB

- New with IMS Version 7
- HALDB Features
  - Partitioned Design allows for very large database size
    - Up to 1,001 partitions with up to 4GB in each partition
  - Usability Features
    - Individual partition(s) may be taken off-line while remaining partitions are in use
    - Large database may be structured into smaller parts for easier management
- Differences from PHDAM / PHIDAM structure
  - DBRC is required for HALDB - partition information stored in RECON datasets
  - DBDGEN is used to define the hierarchical structure of the database
  - ISPF based HALDB Partition Definition utility used to define the partitions
  - If any logically related databases are partitioned all must be partitioned.
  - Bi-directional virtually-paired logical relationships not supported - must be implemented as Bi-directional physically-paired logical relationship
- For further details...
  - REDBOOK - IMS Version 7 High Availability Large Database Guide - SG24-5751-00
  - IMS Version 7 Release Planning Guide - GC26-9437-03
  - Administration Guide: Database
  - At this conference...
    - Session E11 - An Introduction to IMS High Availability Large Databases (HALDB), presented by Vern Watts (Wednesday at 1:15 PM)

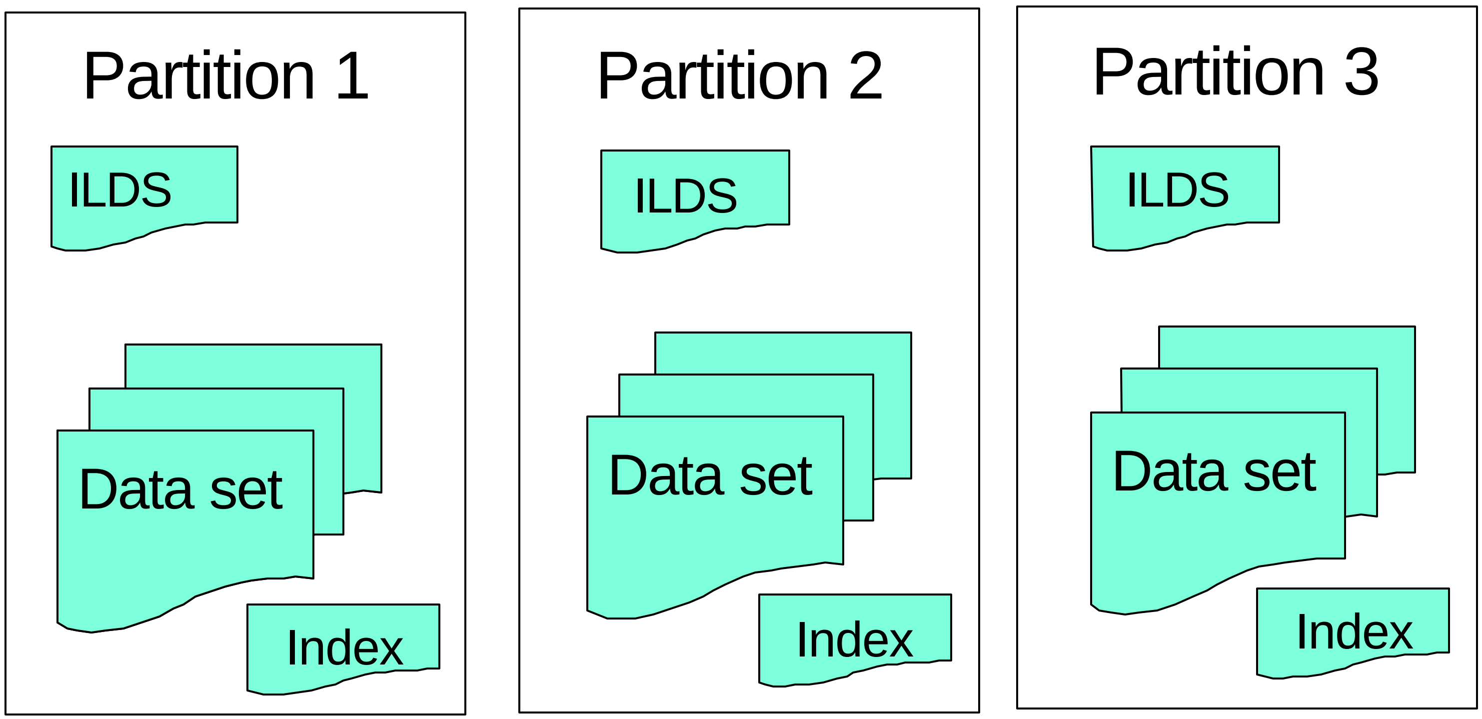
A Quick Look at HALDB

- PHDAM Database
  - Data Set is HDAM structure
  - ILDS - Indirect List Dataset
    - One ILDS dataset per partition
    - Indirect Pointers allow single partition to be reorganized



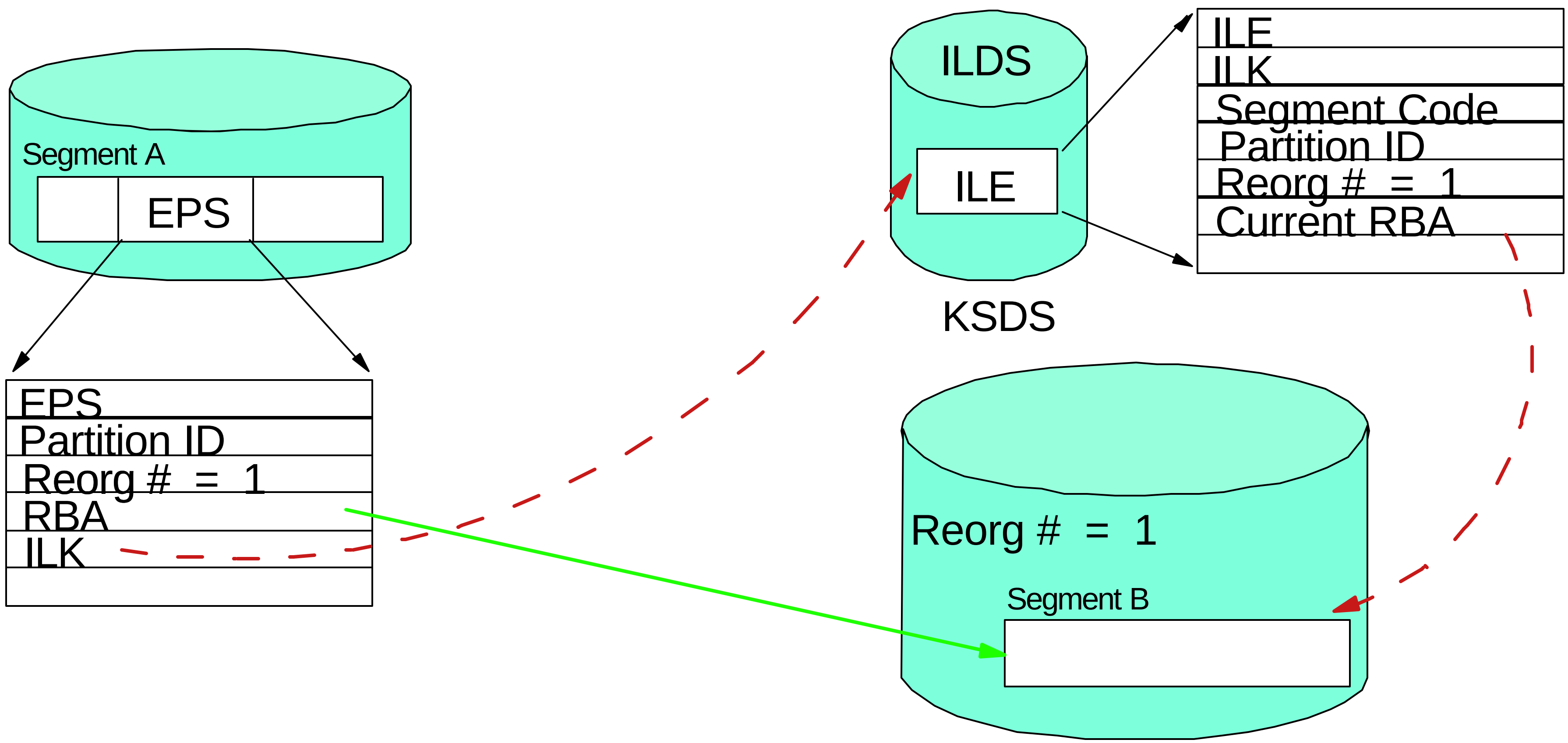
A Quick Look at HALDB

- PHIDAM Database
  - Data Set is HIDAM structure
  - ILDS - Indirect List Dataset
    - One ILDS dataset per partition
    - Indirect Pointers allow single partition to be reorganized



A Quick Look at HALDB

- The ILDS - Indirect List data set
  - If the reorg number matches - use the Extended Pointer Set RBA pointer
  - If the reorg number does not match - use the ILE RBA pointer
  - If update intent - update the EPS information

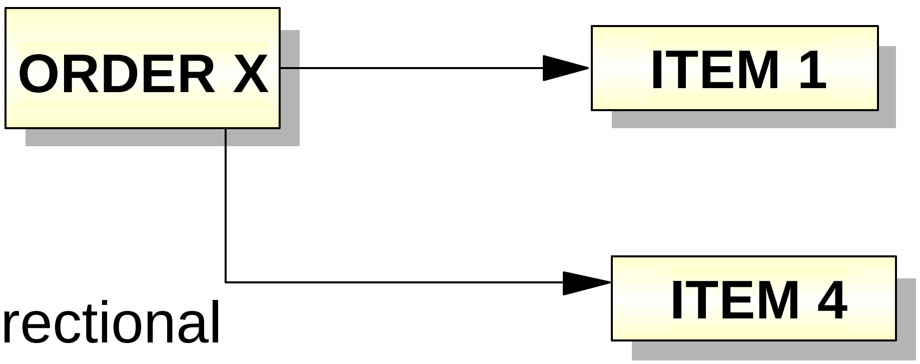


Logical Relations

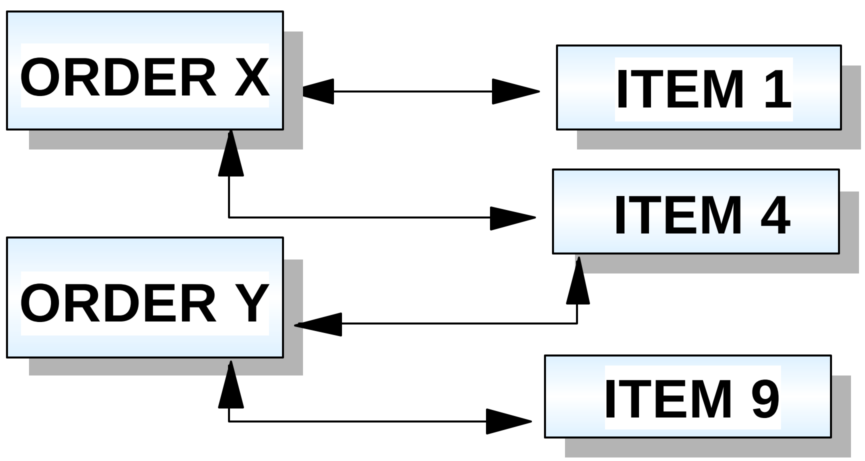
Logical Relations

Types

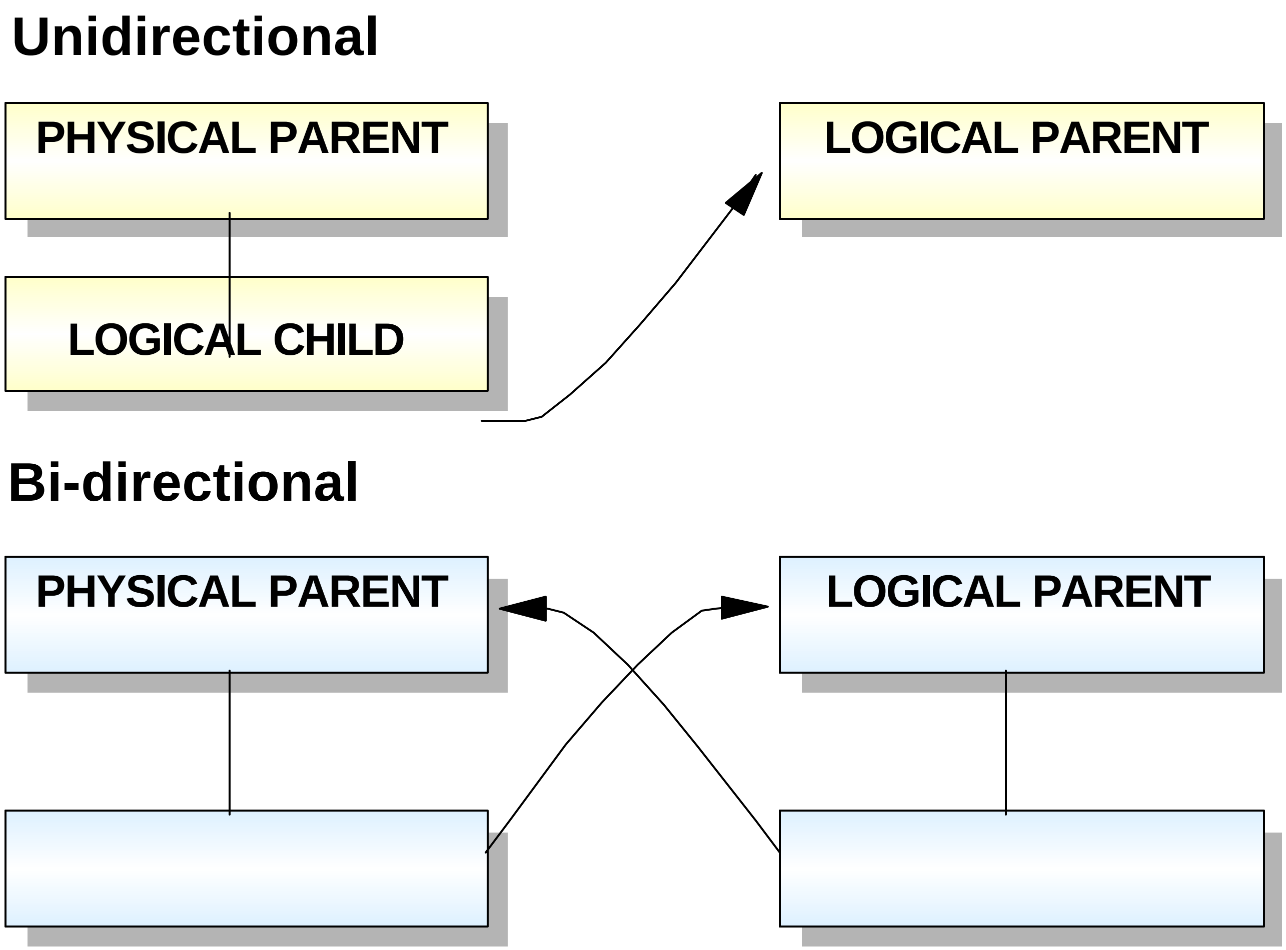
- Unidirectional
  - A one-way relationship from one database record to another
  - Applications always start from one place



- Bi-directional
  - A two-way relationship between database records
  - Applications may start on either side
  - IMS maintains both sides of bi-directional relationships

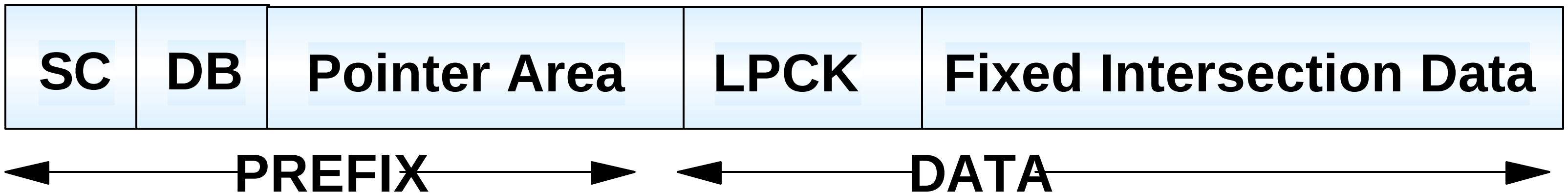


How Logical Relationships are Implemented



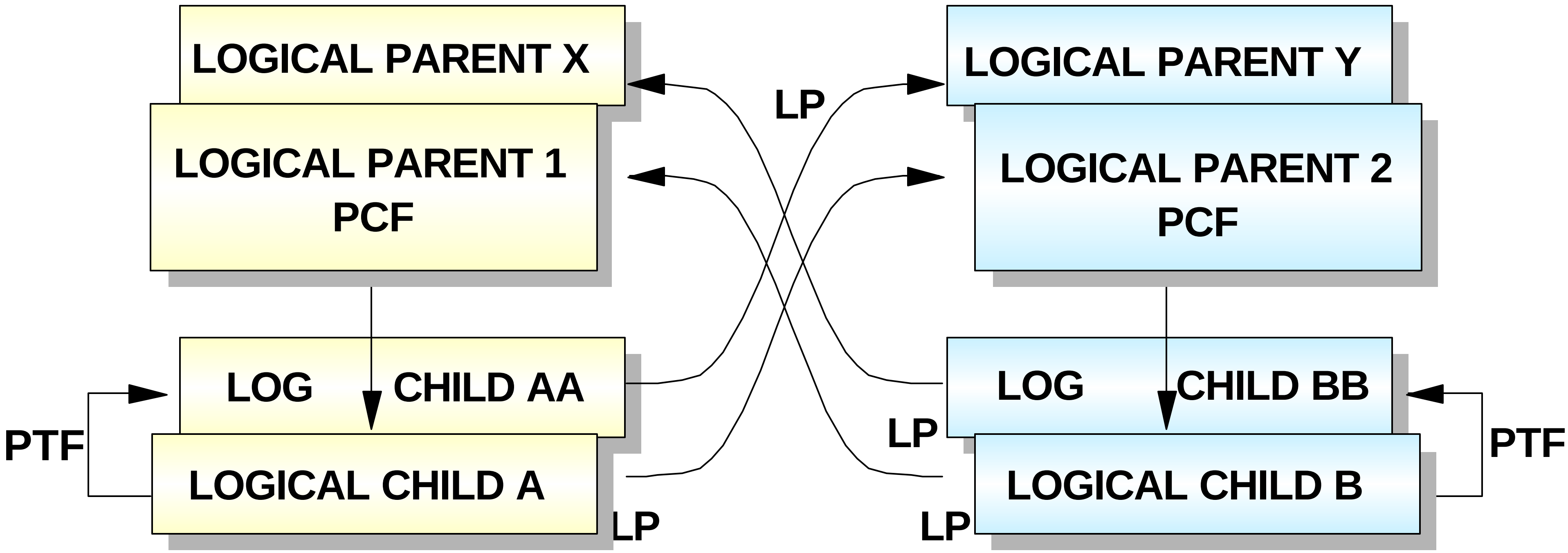
- Logical Parent (LP) Pointer
  - In the Logical Child segment
  - points to logical parent

The Logical Child



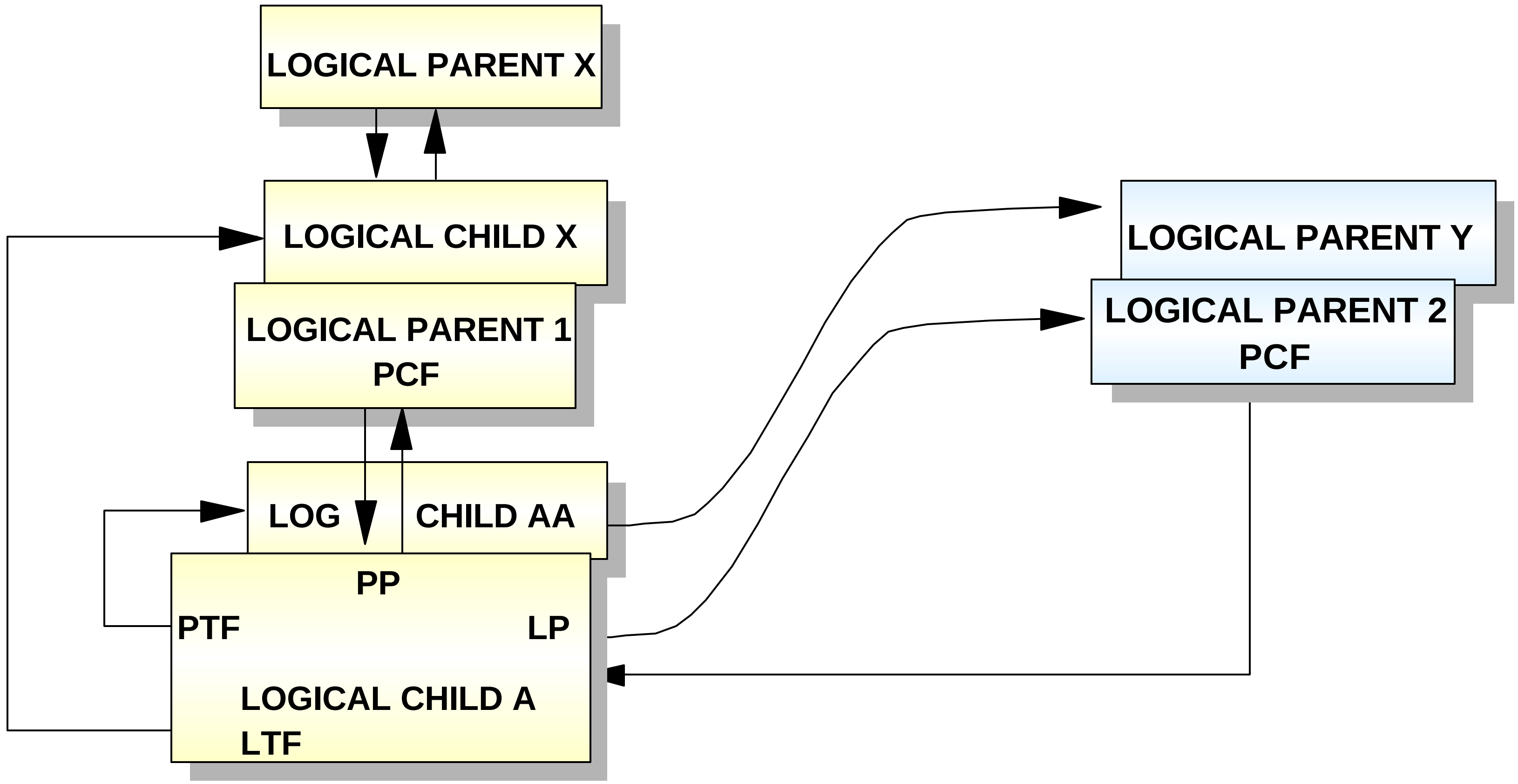
- **Logical Parent Concatenated Key**
  - Sequence fields of all segments from root to logical parent
  - Always appears to the application program
  - May or may not be physically stored with logical child
    - If not stored, IMS generates it on retrieval
- **Logical Parent Pointer**
  - The LPCK if 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 bi-directional relation
  - Variable intersection data is in dependents of the logical child

Bi-directional 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

Bi-directional 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

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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

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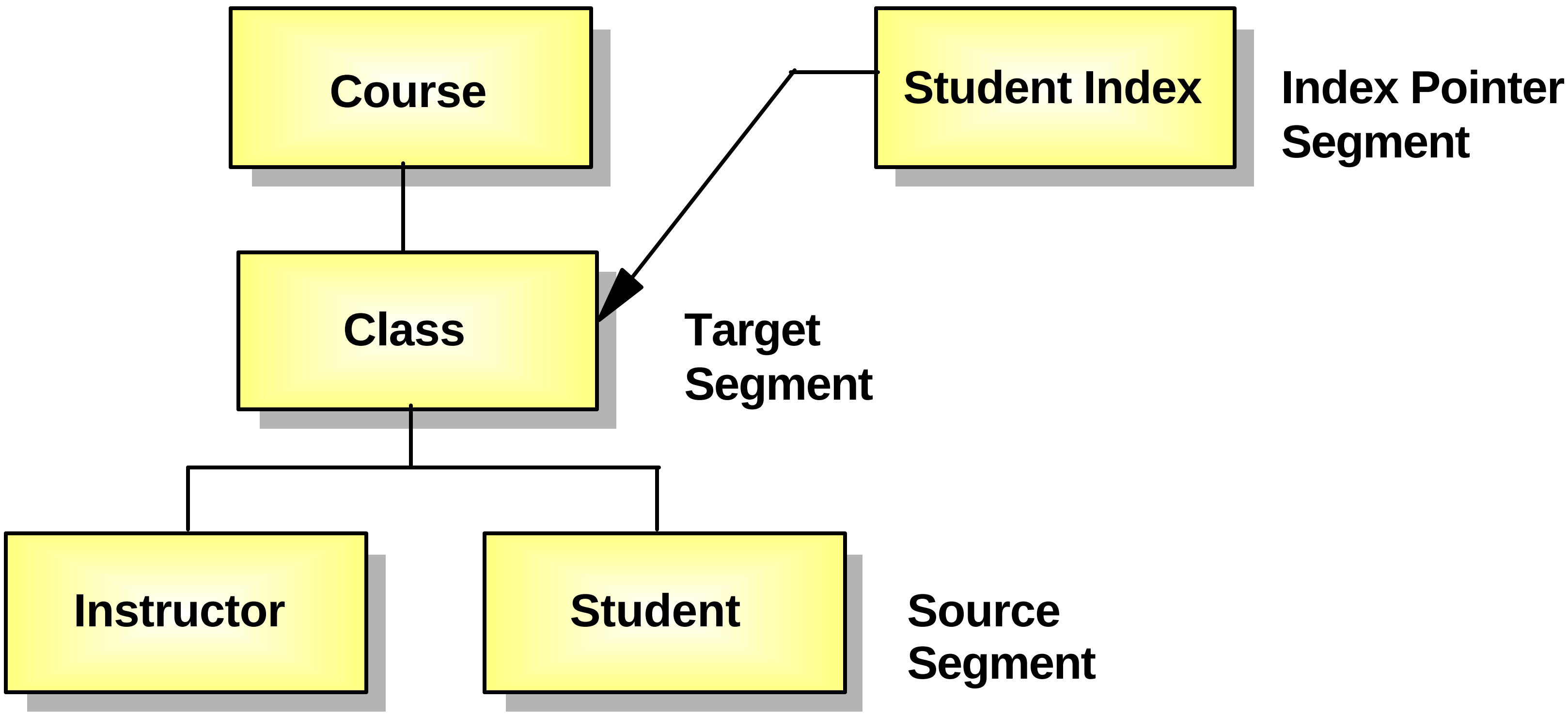
Secondary Indices

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 on one segment type
  - 1000 secondary indices for a database
- Secondary index is a special kind of logical relation

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Fields in the Index Pointer

DB	Pointer	Constant optional	Search	Subsequence 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

Where to look for further information...

- IMS Manuals
  - Administration Guide: Database Manager
    - Chapter 4 - Designing a Full-Function Database, Choosing a Database Type
    - Chapter 5 - Choosing Additional Database Functions
  - Utilities Reference: System
    - Chapter 1 - Database Description (DBD) Generation
- IMS Redbooks
  - IMS Primer (SG24-5352) - Part 3 - IMS Database Manager
    - Four Chapters with very good information on the topics covered in this presentation
- At this conference...

E11	- Introduction to HALDB	Wednesday	1:15 PM	Vern Watts
E30	- Application Design...	Tuesday	8:30 AM	Rich Lewis
E81	- Migrating to HALDB	Monday	2:15 PM	Rich Lewis