DQDB

Distributed Queued Dual Bus
Metropolitan Area Networks
SMDS

Agenda

- Introduction
- DQDB Topology
- DQDB Physical Layer
- DQDB Access Control
- DQDB Framing
- MAN
- SMDS/SIP
MAN/DQDB

- metropolitan area network (MAN) provides
  - integrated services such as data, voice and video
  - high speed transmission of digital bitstreams over a large geographical area

- IEEE 802.6 defines base technology for MAN subnetworks
  - Distributed Queue Dual Bus (DQDB)
  - shared media like a LAN
  - fixed-length packets (cells) like ATM

DQDB subnetwork
- transmission rate between 1 Mbps and 155 Mbps
- shared media communication between DQDB nodes located within an area typically up to 50 km in diameter

usually a public or private MAN consists
- of several DQDB subnetworks interconnected via bridges, routers or gateways

therefore MAN service can cover large regions
- infinite range
IEEE 802.6 DQDB

IEEE 802.6 defines two layers
- DQDB layer (MAC sublayer of OSI layer 2)
- physical layer specification (OSI layer 1)

IEEE 802.6 provides three functions
- connectionless data service
  - MAC service to LLC (Logical Link Control) similar to LAN
  - DQDB plus LLC perform function of data link layer
- connection-oriented data service
  - asynchronous transport of data over virtual channels
  - no guarantee of constant inter-arrival time for data units
- isochronous service
  - transport of data with constant inter-arrival time over an isochronous connection (digitized voice or video)

IEEE 802 compared to OSI

<table>
<thead>
<tr>
<th>IEEE 802</th>
<th>OSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.1</td>
<td>2a Data Link Layer</td>
</tr>
<tr>
<td>802.2</td>
<td>2b Medium Access Control (MAC)</td>
</tr>
<tr>
<td>802.3</td>
<td>802.4</td>
</tr>
<tr>
<td>CSMA/CD</td>
<td>Token Bus</td>
</tr>
<tr>
<td>802.1 Higher Layer Interface (Bridging/Management)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Physical Layer</td>
</tr>
</tbody>
</table>
IEEE 802.6 Layers and Functions

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Dual-Bus Architecture

- End systems (DQDB stations) are connected to DQDB subnet via two unidirectional serial buses:
  - Bus A
  - Bus B

- Bus A and B support communication in opposite direction and full duplex transmission between any pair of stations.

- Station at the head of bus (HOB) generates fixed-length slots of 53 octets which can carry data between stations.
  - HOB A, HOB B

Open Dual-Bus Topology

Diagram showing the dual-bus architecture with HOB A, HOB B, and the connected DQDB stations via bus A and bus B.
HOB

- HOB A is
  - start of data flow for bus A
  - end of data flow for bus B
- HOB B vice versa
- HOB A and HOB B
  - can be in different stations (open dual-bus topology)
  - can be in the same station (looped dual-bus topology)
- looped topology allows
  - automatic recovery from link failure
  - self-healing

Looped Dual-Bus Topology
Reconfiguration

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Physical Layer Options

- DQDB physical layer contains
  - Physical Layer Convergence Procedure (PLCP)
- PLCP is responsible
  - for adaptation of the capabilities of the transmission system in order to transport DQDB slots (53 octet cells)
- PLCP definitions for
  - DS1 (1.544 Mbps)
  - DS3 (45 Mbps)
  - G.703 E1 (2 Mbps)
  - G.703 E3 (34 Mbps)
  - G.703 E4 (140 Mbps)
  - G.707-9 (155 Mbps)

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Access Control

- DQDB allows two access methods
  - pre-arbitrated (PA)
    - used by isochronous service
  - queued-arbitrated (QA)
    - used by data services

- PA
  - for every isochronous connection a unique channel identifier is assigned by network management in advance
    - VCI (virtual channel identifier) field in cell header
  - HOB generates PA-cells with this VCI periodically
    - to satisfy timing constraints of isochronous connection
  - stations can use PA-cells with this VCI value
    - to transmit isochronous traffic across the network

- QA
  - controlled by distributed queuing protocol

- distributed queuing
  - each station has explicit information about queuing state of the network
  - queuing state means, how many cells are waiting for transmission in all stations of the network
  - implemented by special bits in the cell header and counters within the station
    - busy-bit B, request bit R in access control field (ACF)
    - request counter RQ
    - countdown counter CD
Distributed Queuing Protocol

- handling of B-bit and R-bit
  - B and R bits in header of each cell
  - B = 0 ... empty cell, may be used by station for transmission downstream if access control does allow
  - if empty cell is used by a station, B is set to 1 on the fly and payload is filled
  - B = 1 ... busy cell, cannot be used by a downstream station
  - R = 1 ... cell contains a request of an upstream station, cannot be used by another station for signaling request
  - R = 0 ... cell does not contain a request of an upstream station, will be set on the fly by station signaling a request for a cell to downstream stations

Handling of RC and CC Counters
Access Control

- basic access principle
  - explained for access to bus A only (bus B vice versa)
  - if station wants to transmit a cell on bus A
    1. R-bit set to 1 in a cell on bus B to indicate the request must wait for a cell with R-bit equal 0 in order to do this
    2. count value of RQ is copied to CD
    3. RQ is reset
    - actual state of distributed queue is frozen
  - station can use an empty cell on bus A
    - if CD counter has already reached zero and an empty cell arrives
  - this procedure guarantees
    - that every station will satisfy current station requests (cells waiting for transmission in station buffers) first before a cell can be sent
    - cell to be sent is queued in distributed queue

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DQDB Framing

125 usec

Header Slot 1 Slot 2 Slot 3 ........ Slot N Trailer

ACF 1 octet
Segment Header 4 octets
PA/QA Segment Payload 48 octets

VCI 20 bit
Payload Type 2 bit
Seg. Priority 2 bit
Seg. Checksum 8 bit

Busy 1 bit
SL-Type 1 bit
Prev. Seg. Rec. 1 bit
reserved 2 bit
Request 2,1,0 3 bit

ACF, Segment Header

- ACF ... Access Control Field
  - Busy (0 ... slot empty, 1 ... slot contains information)
  - SL-Type ... Slot Type ( 0 ... QA, 1 ... PA)
  - Busy = 0 and SL-Type = 1 reserved
  - Previous Segment Cleared (1 ... clear)
  - Request 2, 1, 0 ... request (R) bits for three priority levels

- Segment Header Field
  - VCI ... Virtual Channel Identifier
    - set to all ones for QA (connectionless service)
    - identifies isochronous channel for PA
  - Payload Type ( 00 ... user data, other values reserved for further study)
  - Segment Priority ( set to 00, other values reserved for multiport bridging)
  - Segment Header Checksum ( x8 + x2 + x +1)
MAC Convergence Function

- basic DQDB framing is not sufficient for connectionless service
  - cell or slot contains no address information about source or destination (VCI = all ones !!!)
- MAC convergence function is necessary
  - to offer to the LLC layer normal MAC datagram functionality
  - to allow transport of variable length LLC packets over DQDB
    - segmenting of LLC PDU into cells
    - reassembling of cells to original LLC PDU

MAC Convergence Function

- MAC convergence function
  - takes MAC service data unit of LLC layer (0 - 9188 octets)
  - builds a so called Initial MAC Protocol Data Unit (IMPDU)
    - header contains information about source and destination, length of PDU, protocol type, QoS, Begin TAG; trailer contains End TAG, CRC, padding
  - splits IMPDU in segmentation units (44 octets), adds header to form a Derived MAC PDU (DMPDU)
    - header contains sequence number, type (BOM, COM, EOM) and message ID of segmentation unit; trailer contains checksum of segmentation unit
  - finally DMPDU (48 octets) fits in the QA Segment Payload of a slot
Mapping IMPDU/DMPDU/QA Segment

Initial MAC PDU (IMPDU)

<table>
<thead>
<tr>
<th>Field</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common PDU Hdr</td>
<td>4 octets</td>
</tr>
<tr>
<td>MCP Header</td>
<td>20 octets</td>
</tr>
<tr>
<td>Header Ext.</td>
<td>0-20 octets</td>
</tr>
<tr>
<td>IMPDU Info</td>
<td>0 - 9188 octets</td>
</tr>
<tr>
<td>PAD</td>
<td>0-3 octets</td>
</tr>
<tr>
<td>CRC</td>
<td>32 octets</td>
</tr>
<tr>
<td>Common PDU Trailer</td>
<td>4 octets</td>
</tr>
</tbody>
</table>

BOM Segment Unit 44 octets

COM Segment Unit 44 octets

COM Segment Unit 44 octets

EOM Segment Unit 44 octets

DMPDU Hdr 2 octets

Segment Unit 44 octets

DMPDU Trailer 2 octets

ACF 1 octet

Segment Header 4 octets

QA Segment Payload 48 octets

Derived MAC PDU (DMPDU)

IMPDU Fields

<table>
<thead>
<tr>
<th>Field</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common PDU Hdr</td>
<td>4 octets</td>
</tr>
<tr>
<td>...............</td>
<td></td>
</tr>
<tr>
<td>Common PDU Trailer</td>
<td>4 octets</td>
</tr>
</tbody>
</table>

reserved 1 octets

BEtag 1 octets

BAsize 2 octets

reserved 1 octets

BEtag 1 octets

Length 2 octets

reserved ... set to zero for transfer of IMPDU

BE (Beginning-End) tag ... value selected by MAC convergence function to allows association of the BOM DMPDU with EOM DMPDU

BA (Buffer Allocation) size = Length ... number of octets MCP Header -> CRC32
### IMPDU Fields

<table>
<thead>
<tr>
<th>Common PDU Hdr</th>
<th>MCP Header</th>
<th>..........</th>
<th>Common PDU Trailer</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 octets</td>
<td>20 octets</td>
<td></td>
<td>4 octets</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Destination Address</th>
<th>Source Address</th>
<th>Protocol Identifier</th>
<th>Pad Length</th>
<th>QoS Delay</th>
<th>QoS Loss</th>
<th>CRC32 Indic.</th>
<th>Hdr. Ext. Length</th>
<th>Bridging reserved</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 octets</td>
<td>8 octets</td>
<td>6 bits</td>
<td>2 bits</td>
<td>3 bits</td>
<td>1 bits</td>
<td>1 bits</td>
<td>3 bits</td>
<td>2 octets</td>
</tr>
</tbody>
</table>

Address Type: 4 bits
Address: 60 bits

- source addresses can be individual only,
- mapping of 16 or 48 bit addressing in 56 bit done by padding remaining bits (left to right),
- assignment of E.164 addresses (country code) is administered by CCITT according to Numbering Plan for the ISDN Era
- E.164 uses decimal numbers encoded using BCD starting with 0xC (individual) or 0xE (group)

<table>
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<td>QoS Loss</td>
<td>CRC32 Indication</td>
<td>Hdr. Ext. Length</td>
<td>Bridging reserved</td>
</tr>
<tr>
<td>... set to 1 for LLC, 48-63 available for use of local administration, other values reserved for future standardization by IEE 802.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>... (0-3) number of Pad octets after INFO; INFO plus PAD must be an integral multiple of four octets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>... contains priority bits (7 ... shortest, 0 ... longest delay)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reserved (set to zero)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>... indicates presence or absence of CRC32 checksum field</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>... length of Header Extension field (multiple of four octets)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>... reserved for future use with MAC Sublayer bridging (set to zero)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DMPDU Fields

- Segment Type: 2 bits
- Sequence #: 4 bits
- Message ID: 10 bits
- Payload Length: 6 bits
- Payload CRC: 10 bits

Segment Type ...
- 00 Continuation of Message (COM), 01 End of Message (EOM)
- 10 Begin of Message (BOM), 11 Single Segment Message (SSM)

Sequence # ....... sequence number of DMPDU, used for reassembling IMPDU

Message ID ....... identifies all DMPDUs of original IMPDU using the same value;
(every station is assigned a unique identifier by DQDB layer management, which is used
as message ID; like TEI in ISDN)

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MAN Hierarchy

- MAN is based on DQDB subnetworks
- DQDB subnetworks are shared media
- privacy problem if DQDB subnetworks should offer a public transport service to different customer
- therefore public MAN services
  - are built on hierarchical network topology
  - central public DQDB subnetwork to interconnect edge gateways (EGW)
  - several independent private DQDB subnetworks with customer gateways (CGW) as access stations
  - private DQDB subnetworks are used by one customer only and are connected to EGW

MAN Hierarchy (EGW/CGW)

- Private subnetworks for customers A and B
- Central public MAN subnetwork (MSS)
- Edge gateways (EGW) interconnect with customer gateways (CGW)
- Ethernet and Token Ring connections

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DQDB, v3.4
**MAN Hierarchy (EGW/CGW)**

- **CGW**
  - Customer networks such as LAN’s, Frame Relay are connected to CGW which provides normal bridging or routing functionality over MAN.
  - Several CGWs can form a private DQDB subnetwork in order to connect different locations (e.g. campus).
  - Private DQDB subnetwork is controlled by customer.
  - Small customer locations can be connected EGW directly to avoid high cost of CGW.
    - Point-to-point link between router and EGW.
      - SMDS interface protocol (SIP)
      - DXI Data Exchange Interface (DXI)
      - SMDS DSU (“DQDB modem”)

- **EGW**
  - Is responsible to provide security and privacy to customer using MAN transport services.
  - Is controlled by service provider only.
  - Works as transparent bridge between private and public DQDB subnetworks.
    - Store and forward device (IMPDU packet switch with connectionless service).
    - Transparent bridging based on E.164 addresses.
  - Privacy guaranteed by EGWs.
    - Filtering functions of transparent bridge.
    - Mapping of customers broadcasts to customer specific E.164 group/multicast addresses.
MSS

- public DQDB network
  - consists of EGWs and DQDB trunk lines
  - MSS (MAN Switching System)
- countrywide public MAN service
  - can be built by interconnection of MSSs
  - done by DQDB routing functionality

Interconnection of MSS
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SMDS

- Switched Megabit Digital Service
  - high-speed, connectionless, public packet switching service to extend LAN-like performance beyond the subscribers premises across a MAN or WAN

- SMDS is broadband networking technology developed by Bellcore
  - subset of IEEE 802.6; access to SMDS via DQDB
  - specifies interfaces and protocols to be used between user and SMDS provider
    - SNI (Subscriber Network Interface)
    - SIP (SMDS Interface Protocol) based on DQDB
  - internal implementation of SMDS different to 802.6
SIP

- **SIP Level 3**
  - format the same as for IMPDU of DQDB
  - variable frame length 0 - 8199 octets

- **SIP Level 2**
  - consists of DMPDU plus segment header and trailer
  - 53 octets cells

- **SIP Level 1**
  - defines PLCP for DS1 (1.544 Mbps), DS3 (45 Mbps)
DXI:

- to allow easy upgrade of existing equipment such as bridges or routers to DQDB/SMDS
  - DXI (Data Exchange Interface) protocol was defined
- DXI allows
  - communication between CPE (router) and DSU using normal serial interface technology and HDLC like framing
    - use of HDLC address field, UI and Test frames only
  - router is responsible for creating SIP Level 3 IMPDU
  - router will carry IMPDU’s in HDLC frames to DSU
  - DSU will provide splitting of IMPDU into DMPDUs and generating of DQDB cells in order to transmit DMPDUs
Summary

- DQDB (IEEE 802.6) is base technology for MAN
- three services
  - connectionless data (LAN-LAN)
  - connection oriented data (virtual channel)
  - isochronous (voice, video)
- dual-bus shared media
- access control by distributed queuing protocol
- data services need convergence functions
  - to assemble and reassemble packets into DQDB cells
- SMDS service description
  - based on IEEE 802.6, connectionless only, SIP, DXI