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JOHN F. KENNEDY SPACE CENTER
UNIVERSITY OF CENTRAL FLORIDA

DESIGN AND EVALUATION OF FDDI FIBER OPTICS NETWORK FOR ETHERNETS, VAX'S AND INGRAPH WORK STATIONS

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Mr. Hank Perkins for valuable assistance and genuine interest in FDDI project. Patrick O'Rourke and Ed Bertot for valuable support along the way. Bryan Boatright for practical suggestions related to FDDI system design.

Last but not least, I would like to thank Dr. Loren Anderson of U.C.F. who managed the Summer Faculty Program.

Abstract

The purpose of this project is to design and evaluate the FDDI Fiber Optics Network for Ethernets, VAX's and Ingraph work stations.

From the KSC Headquarters communication requirement, it would be necessary to develop the FDDI network based on IEEE Standards outlined in the ANSI X3T9.5, Standard 802.3 and 802.5 topology - direct link via intermediate concentrator and bridge/router access.

This analysis should examine the major factors that influence the operating conditions of the Headquarters Fiber plant. These factors would include, but are not limited to the interconnecting devices such as repeaters, bridges, routers and many other relevant or significant FDDI characteristics.

This analysis is needed to gain a better understanding of overall FDDI performance.

List of Acronyms

KSC - Kennedy Space Center

ANSI - American National Standards Institute

FDDI - Fiber Distributed Data Interface

LAN - Local Area Networks

OSI - Open System Interconnection

OSIRM - Open System Interconnection Reference Model

MAC - Medium Access Protocol

BET - Bit Error Rate

SAS - Single Attachment Station

DAS - Dual Attachment Station

MIC - Media Interface Connections

STP - Shielded Twisted Pair

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1. INTRODUCTION

1.1 General

In today's high pressure business environment, acquiring and distributing information quickly is critical to the functioning of most companies. Networks play an increasingly important role in this process. In this project - choosing the right network, however, is a complicated one. Many factors such as propriety networks, nonstandard applications and single vendor hardware sourcing need to be taken into consideration. Network standards such as Fiber Distributed Data Interface (FDDI) help to simplify this task. The current HQ's ethernet system based on 10 Mbs. standard transmission is going to be replaced by a new LAN operating at 100 Mbs. In such architecture, network systems are designed in layers performing a special set of functions and services. Each layer has it's own protocols, regulating activities within the layer as well across links between stations called nodes, and is independent of each other. The open system interconnection (OSI) with interoperability or open communications supports multivendor communication.

1.2 FDDI Background

The FDDI grew out of the need for high speed interconnections among mainframes, minicomputers and associated peripherials. In October 1982 ANSI committee X3T9.5 was chargered to develop a high speed data networking standard that specified a packet switching LAN backbone that transported data at high throughput rates over a variety of fibers. The FDDI specifications encompass a token passing network enveloping two pairs of fibers operating at 100 Mbs. The 1991-1992 standard covers the first two layers of OSIRM through the MAC sublayer. The optical based FDDI-LAN was designed to enjoy the same type serial interconnection provided by LAN's while providing a high band width, inherent noise immunity, and security offered by Fiber. The FDDI is meant to provide inexpensive connectinity, thus it focuses on the 100 Mbs rates. The FDDI accommodates a synchronous data transmission and is designed as a fiber optic network. The standardization involves duplex optical connectors, fiber characteristics, optical band width, bypass relays and cable assemblies and is designed on overal BER $<10^{-9}$. The network can tolerate up to 11 dBm between the stations, and can support a total cable distance of 100 km around the ring with 500 attachments. The intrinsic topology of FDDI is a counter-rotating token-passing ring. At least part of the reason why FDDI employes a ring topology is based on the characteristics of the optical communication. Bus and passive star topologies would require the optical to be detected at several sources simultaneously. Although, practical fiber optical taps are beginning to become available, the attenuation is still such that number of nodes is relatively limited. Because the fiber optical transmission is best handled with a point-to-point configuration, this aspect is included in FDDI's definition.

1.3 FDDI Standards

Institute of Electrical and Electronics Engineers.

IEEE Std. 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access method and Physical Layer Specifications.

IEEE Std. 802.5 Token Ring access method and physical layer specifications.

IEEE Std. 802.1.a Overview of Local Area Networks (LAN) and Metropolitan Area Networks (MAN) specifications.

IEEE Std. 802.1.d Local Area Networks (LAN's) MAC Transparent Bridging Standards.

IEEE Std. 802.1.i Mac Layer Bridge FDDI supplement.

IEEE Std. 1003.1 Portable Operating System Interface (POSIX).

Ethernet Version 2. A Local Area Network: Data Link Layer and Physical Layer Specification. DEC Intel and Xerox Corp. Version 2.0, Nov. 1982

American National Standard Institute, Inc.

X3.139 FDDI Token Ring Media Access Control Standard

X3.148 FDDI Token Ring Physical Layer Protocol Standard

X3.166 FDDI Token Ring Physical Layer Medium Dependent Standard

X3T9.5 FDDI Station Management (Rev. 6.2)

2. SYSTEM ARCHITECTURE

2.1 Introduction

Network systems are designed in layers. Each layer performs a special act of functions and services. Each layer has its own protocols, regulating activity as well communication and transfer of data between layers and across links. The layers are independent of each other. This layered approach means that designing networks and network functions is easier and networks can provide users with a greater range of accessible and ease-to-use capabilities.

2.2 Open System Interconnection.

OSI is a seven-layer model for an open network atchitecture with high interoperability or open communication. It supports multivendor communication and provides a framework for the development of international standards for computer communication.

The OSI model shown in Fig. 1 was developed by the International Organization for Standardization and InternationalTelegraph and Telephone Consultative Committee.

The physical layer specifies the electrical and physical connections between systems. This layer also translates messages into a form that is compatible with the medium used; for example, fiber or coax cable.

The data link layer introduces control information into messages that are to be transmitted, defines frame construction, addressing error detection and connection to higher layers.

The network layer permits communications between network nodes in an open network, establishes and releases the logical connections for data transfer between communicating nodes and controls the flow of messages between nodes.

2.3 The OSI Model

Repeaters, bridges, and routers link networks together. The simplest network interconnecting device is a repeater (Fig. 2). It acts on the bits transferred between the physical layers of two nodes; it repeats, retimes, and simplifies the bits.

A bridge, called also a data link relay, links similar and dissimilar LANS together to form an extended LAN. (Fig. 3).

Bridges act on the frames transferred between the Data Link Layers of the two nodes, while reactors act on the bits transferred between physical layers.

Bridges are designed to store and then foward frames destined for another LAN and they are also protocol independent. Ideally, bridges are invisible to the cut-stations that are communicating through the bridge. The end-station does not know that the bridge exists or that the message is going through the bridge.

Routers also called an intermediate system, network relay or level 3 relay (Fig. 4) are used to link LAN's. Routers are typically network layer (Layer 3) devices. Routers act on the frames transferred between the Network layers of two nodes. Routers are known to the end-station. Nodes periodically send messages to the routers confirming their existence and their address. The router keeps a record of node addresses and current network status. It forwards a message directly to a local or remote LAN over the route with the least amount of traffic or lowest cost as defined by the network manager. Routers isolate LAN's into subnetworks that can manage and contain network traffic.

2.4 The LAN's Function

LAN - Local area networks connect computers, terminals, and other equipment in the building or on a campus. Bridges connect LAN;s over distances that exceed the capabilities of a single LAN. OSI standards allow different types of LAN's to be linked together. For example two IEE 802.3 networks can be connected with an 802.3/Ethernet bridge.

Fiber Distributed Data Interface is a new multivendor local area network standard developed under ANSI that offers an industry-standard solution for organizations that need flexible, robust, high-performance networks. ANSI has defined the FDDI to be 100 Mbs. LAN featuring the timed-token protocol and supports a dust ring of trees topology. For multimode fiber optic cable used as a transmission medium, the standards specify: optical cable consisting of 62.5/125um, graded index multi mode fibers, a maximum fiber length of 200km with a maximum of 2km between adjacent stations, and a maximum of 500 stations.

2.5 FDDI Topology

An FDDI network consists of physical and logical topologies. The physical topology refers to actual arrangement of the cables and hardware, where the cable can be a line, link, circuit, transmission medium ot channel.

The logical topology refers to the actual path, which varies, depending on traffic flow and the number and location of active stations on the network. Typical configuration for the FDDI is implemented in three ways:

1. As a high-speed backbone connecting mid-speed local area networks.
2. As a high-speed LAN connecting code stations or other devices.
3. As a high-speed connection between host computers.

As FDDI standards, ANSI permits the following topologies:

1. Stand alone concentrator with attached stations.
2. Dual ring.
3. Tree of concentrators.

4. Dual ring of trees.

The stand alone concentrator topology consists of a single concentrator and its attached stations (Fig. 5). These stations can be either single attachment stations (SAS) or dust attachment station (DAS) devices.

This topology can use existing structured fiber optic cable, affording significant cost savings in prewired sites. The dust ring topology shown in Fig. 6 consists of dust attachment stations connected directly to the dust ring. This topology is useful with limited number of users, however, does not easily lend itself to additions, moves or changes.

Because each station is part of the backbone wiring, the behavior of each user is critical to the operation of the ring, and disconnecting a dual attachment workstation causes a break in the ring. In the event of a single failure, a dual ring provides a secondary transmission path, however, multiple failure results in no access to the other rings. In addition, dual, attachment stations require twice the number of connectors and cables, and manual intervention and manipulation of cables results in ring instability in large installations.

The preferred choice when wiring together large groups of user devices is the tree of connectors shown in Fig. 7.

The concentrators are wired in a hierarchical star topology with one concentrator serving as the root of the tree called a HUB. This topology provides greater flexibility for adding and removing FDDI concentrators and stations or changing their location without disrupting the FDDI LAN. The tree configuration connects all stations in a single building or a large number of stations on one floor of a building.

The tree topologies allow network managers to better control access of end-user systems to the network. Inoperative systems can be easily removed from the network by the concentrator, and the network manager can remotely address the concentrator to bypass the device.

In dual ring of trees concentrators cascade from other concentrators connected to a dual ring. Fig. 8.

This configuration places the dual ring where it is needed most - in the campus backbone.

The dual ring of trees is the recommended topology for FDDI. It provides a high degree of fault tolerance and increases the availability of the backbone ring. Also, in this configuration, stations attached to concentrators can be removed from the FDDI LAN as needed. Concentrators can then bypass inactive or defective stations without disrupting the network.

3. REQUIREMENTS

3.1 Introduction

The proposed equipment for the Head Q's (Fig. 9) third floor shall be configured to satisfy specific requirements based on the current KSC networking environment such as:

Local Area Network's (LAN) requirements currently based on 802.3 and 802.5 topologies (ANSI X3T9.5). Direct link shall be provided via intermediate concentrators and bridge/router access. Linking the above networks shall require networking segmentation capabilities including network control, monitoring and management functionality.

3.2 FDDI Concentrator Requirements

3.2.1 Basic Requirements

1. The concentrator shall implement all required sections of the ANSI X3T9.5 FDDI standard including ANSI X3.139, X3.166, X3.148, as well as FDDI Station Management (SMT) version 6.2

2. The concentrator shall be capable of connecting to the FDDI dual counter - rotational ring as a Dual Attached Station (DAS) or as a Single Attached Station (SAS) and support connection in a tree.

3. The concentrators shall display the status of each port, power status, and an operational status indicating whether the concentrator is fully operational. (Using LED's or LCD panels)

4. Physical interface through the Media Interface Connections (MIC) shall support the FDDI duplex plug that terminates the optical fiber from the network with losses less than 1dB for a plug to receptacle.

5. The optical interface - MCI shall support a 62.5/125 or a 50/100 core/clad multimode graded index, 500 MHZ -km fiber duplex connector.

3.2.2 General highly desirable requirements.

1. The electric interface - the concentrator shall provide support for an implementation of FDDI over IBM type 1,2, and 6 shielded twisted pair cabling (STP) for a distance up to 100m.

3.3 Interfacing LAN's

There are many differences among FDDI local area network standards ranging from the type of media to speed of transmission, nodes transmission, size of the single message, nodes encoding of message and distance between nodes.

The FDDI, IEEE 802.3 and 802.5 standards define different topology. IEEE 802.3 is a local bus topology. The 802.5 specifies local ring topology as a single ring topology. A failure on a single ring topology causes the ring to fail. IEEE 802.5 isolates the failure, but does not always recover. FDDI specifies a dual counter-totating ring topology. It also defines the tree and dual ring of trees topology that can be installed as hierarchial star in a structured cable plant. The FDDI dual counter-rotating ring is a robust fault-tolerant structure that ensures data flow in case of failure.

Table I compares the topologies specified by the FDDI, IEEE 802.3 and IEEE 802.5 standards.

Table II does comparison of media for LAN transmission.

Comparison of band width is shown in Table III, where band width is a measure of the amount of traffic the media can handle at one time.

And finally Table IV summarizes the differences and similarities among the FDDI, IEEE 802.3 and the IEEE 802.5 standards.

4. DESIGN, SYSTEM SELECTION AND IMPLEMENTATION OF FDDI

4.1 Introduction

The decision for FDDI depends on the following factors:

1. Type of LAN applications used by organization.
2. Current extent of LAN use.
3. Prediction on the nature of future LAN applications.
4. Predictions on future volume of LAN traffic.

When planning for the backbone system, network planners need to:

1. Choose vendors that provide a platform for a non proprietary open solution.
2. Understand the role and technology of bridges and routers that tie FDDI networks to sub-LAN's, the difference between SAS and DAS devices and advantages of concentrators, the advantage of the dust ring of trees topology.
3. Understand the FDDI management options.

The proprietary solutions-in the backbone systems can be costly because it leads to reliance on a single vendor for networking solutions, and prevents the organization from responding to evolving networking needs. The nonproprietary systems solution includes components from many vendors, and upgrades are done through software changes, thus providing flexibility and investment protection.

In choosing bridges or routers for FDDI, there are distinctly different uses for each LAN-to-LAN connections. Use bridges for the LAN-to-LAN interconnection when the requirements are for low delay and high throughput. Use routers for the LAN-to-LAN interconnection when longer delay and low performance are acceptable and a high degree of insolation or control is required.

Before implementing FDDI, the questions relating to current LAN use can be answered accurately only by a thorough analysis of current levels of traffic and prediction of future traffic volumes must be based on trend analysis of current traffic patterns.

Appendix A provides a current testing for Ethernet traffic for the third floor Headquarters building, and Fig. 9 shows the space utilization with existing traffic.

4.2 FDDI Implementation

This includes:

1. Determine the configuration and extent of the existing cabling systems.
2. Develop the cable strategy if none exists.
3. Pull the cable within a building.
4. Bring the fiber to the work area on an as needed basis by running fiber optic cable from the wiring closet to the wall outlets in user offices.

Fig. 10 indicates the global plan for KSC FDDI transmission system in Phase I. Based on the Phase I plan for the KSC the Headquarters implementation is shown in Fig. 11. This decision on implementation of FDDI depends on current use and predicted future use, network size, and traffic flow on the network. When choosing components to implement an FDDI network the proprietary solution was avoided.

Bridges and routers both have their place in a network, however, bridges are used for low delay and high throughput, and routers are used when a high degree of isolation or control is required.

DAS workstation connection is used for small workgroups, and SAS and concentrator connections provide manageability reliability and expansion for networks as the demand increases.

The dual ring of trees topology is recommended topology because it protects the backbone from multiple failures, grows as the demand increases, and is easily maintained.

4.3 FDDI System Realization

FDDI is the one technology that consistently meets the latest high-performance corporate networking and communications criteria. The proposed structure for the KSC Headquarters; a nonproprietary implementation shown in Fig. 10 is widely accepted and supported in the industry as the next generation international standard for high-speed multivendor networking interconnections. In such configuration, standard SAS devices such as bridges, systems, and workstations are directly connected to the FDDI LAN through the concentrator, thus providing for the addition or removal of SAS or DAS devices in a nondisruptive manner. The operational integrity of the backbone and midspeed subnetworks is preserved.

4.4 FDDI Products.

4.4.1 The DEC concentrator 500 in modular configuration provides for the attachment of FDDI devices such as workstations, systems and Bridge 500s or other concentrators to the FDDI network.

4.4.2 The DEC bridge 500 provides the interconnection between a midspeed 10MB/s802.3/Ethernet LAN and high speed 100 MB/s FDDI network backbone.

A self-learning intelligent hardware device, it performs standard bridge functions such as filtering and forwarding, and transparent translation of network data between the FDDI and 802.3/Ethernet networks. The DEC Bridge 500, protocol-independent, accomodates multiple protocols.

4.4.3 The DEC FDDI controller 700 provides a direct FDDI connection for a digital high-performance RISC-based work station and brings the speed of FDDI to the desk top, it is a low-cost, high-performance interface option that is implemented as a SAS device. Attaches directly to the FDDI network through the DEC concentrator 500, which provides protection from network disruption and allows configuration flexibility.

5. Conclusion

By selecting Digitals, a nonproprietary solution for a Kennedy Space Center Headquarter's FDDI network, one has selected a secondary generation LAN technology that consistently meets the latest high-performance corporate networking and communications criteria.

Since FDDI is now widely accepted and supported in the industry as a next generation international standard for high-speed multivendor networking interconnection, this selection is most appropriate. The decision to implement FDDI network depends on a current use and predicted future use, network size, and traffic flow on the network. When choosing this realization, the stress was placed on a nonproprietory solution which includes components from a single vendor or from many vendors. In such case, upgrades frequently are done through software changes, thus providing flexibility and investment protection.

6. Future Research Suggestions

In order to maximize performance of the Kennedy Space Center LAN network, one must provide a framework for the management of heterogeneous, multivendor systems. Management functions are used by network - and system - level personnel to monitor, control, maintain the network - A comprehensive network management system provides for configuration, fault, performance, accounting, and security management.

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Figures

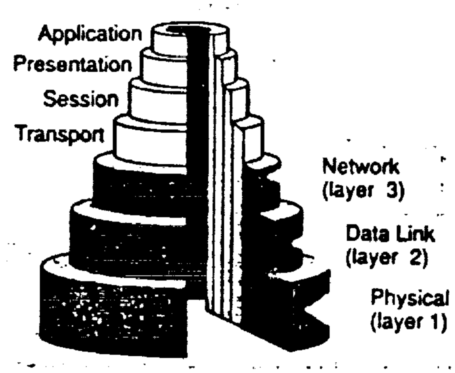


Figure 1 • The OSI model

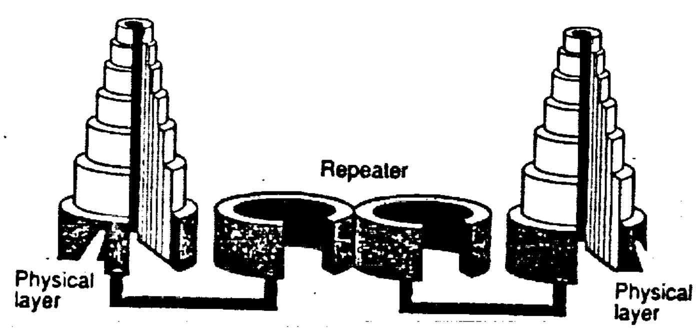


Figure 2 • OSI layer handled by a repeater

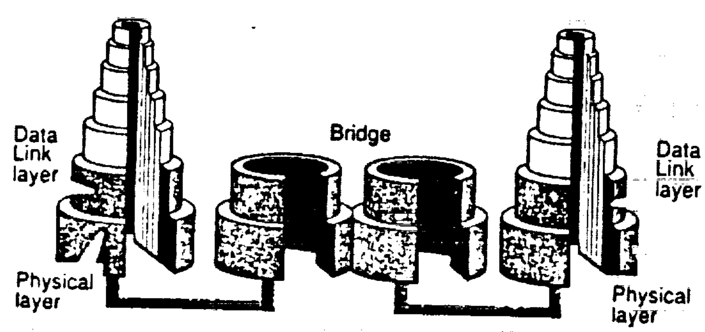


Figure 3 • OSI layers handled by a bridge

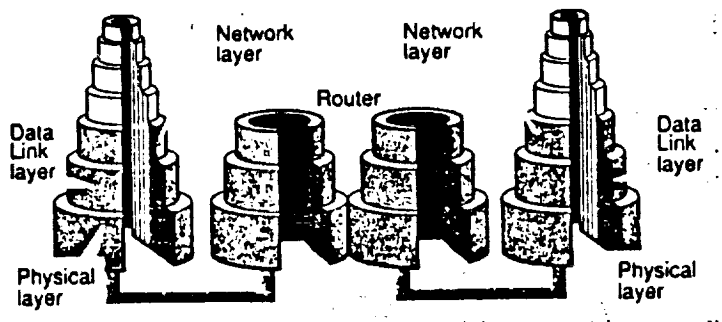


Figure 4 • OSI layers handled by a router

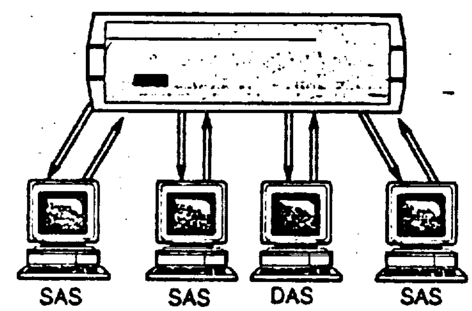


Figure 5 • Standalone concentrator topology

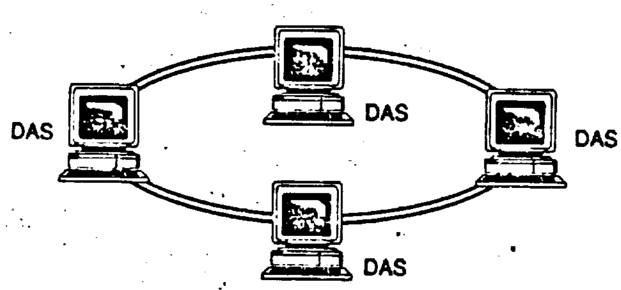


Figure 6 • Dual ring

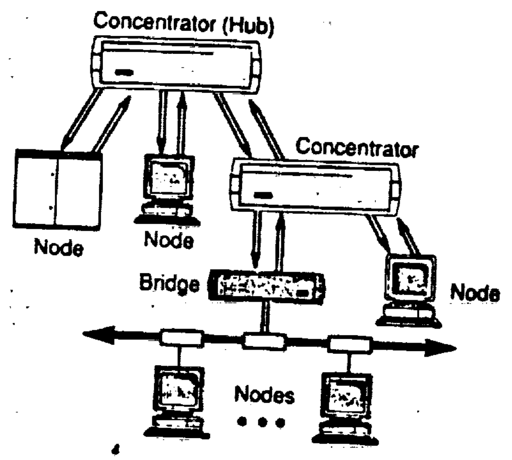


Figure 7 Tree of concentrators wired in a hierarchical star configuration

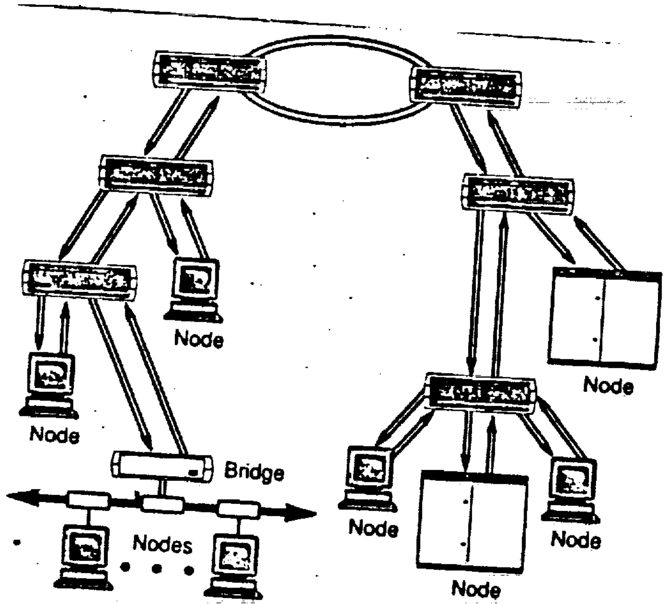
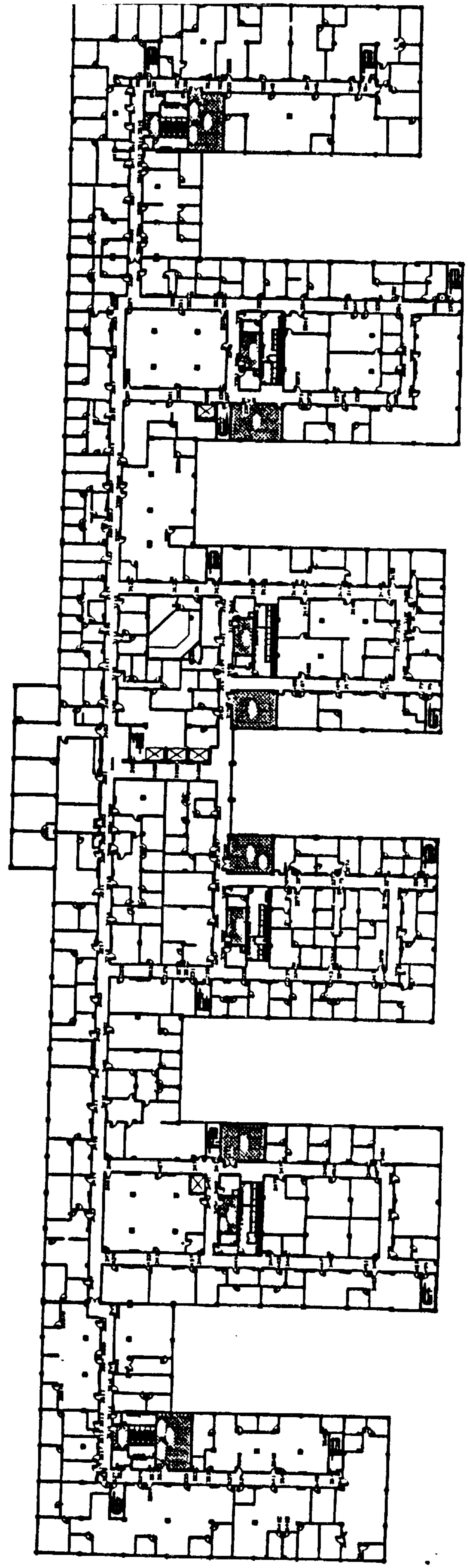


Figure 8 Use of concentrators in the dual ring of trees topology



National Aeronautics and Space Administration
John F. Kennedy Space Center
ENGINEERING DEVELOPMENT DIRECTORATE

FDDI NETWORK PROJECTS & STATUS

APRIL 16, 1992

J. B. BOATRIGHT

FDDI Transmission System

Preliminary Layout - PHASE 1

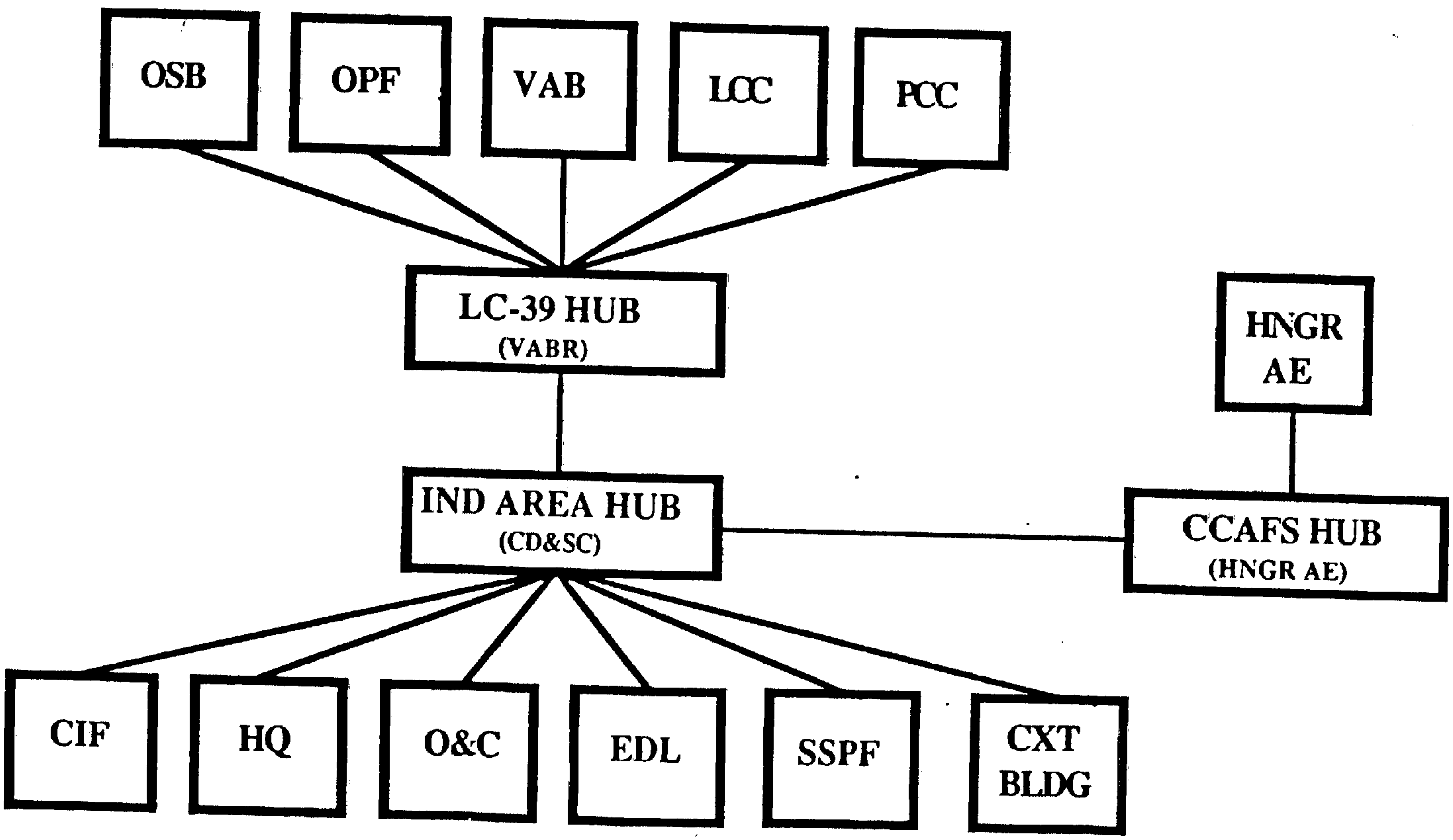
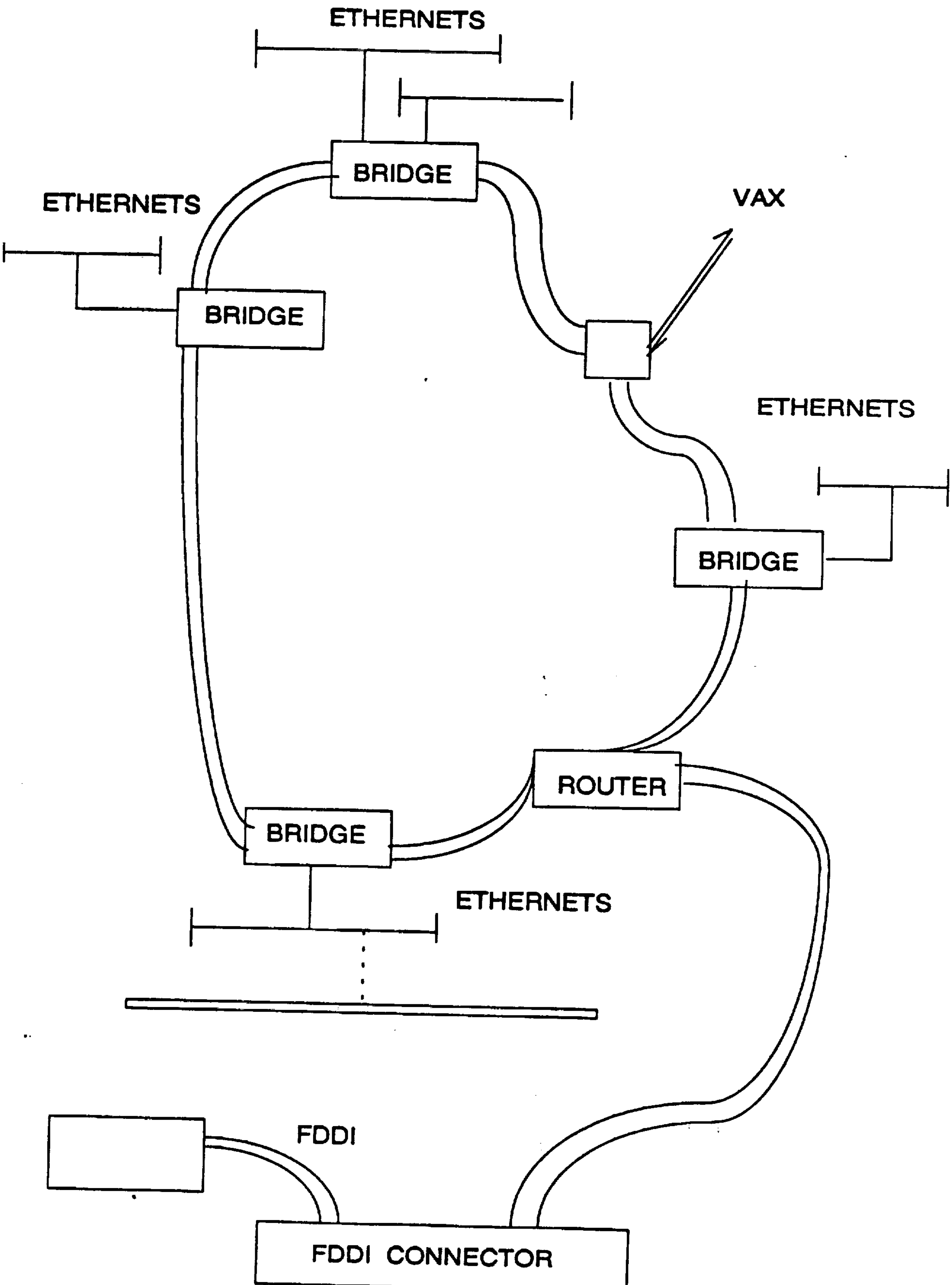


FIG. 10

FIG. 11


ETHERNETS
BRIDGE
ETHERNETS
BRIDGE
VAX
ETHERNETS
BRIDGE
ROUTER
BRIDGE
ETHERNETS
FDDI
FDDI CONNECTOR

Tables

Table 1 • Comparison of topologies

	FDDI	IEEE 802.3	IEEE 802.5
Logical topology	Dual ring, Dual ring of trees	Bus	Single ring
Physical topology	Ring, Star, Hierarchical star	Star, Bus, Hierarchical star	Ring, Star

Table 2 • Comparison of media

	FDDI	IEEE 802.3	IEEE 802.5
Media	Optical fiber	Optical fiber, Twisted-pair, Coaxial cable, Microwave	Twisted-pair, Optical fiber

Table 3 • Comparison of bandwidth

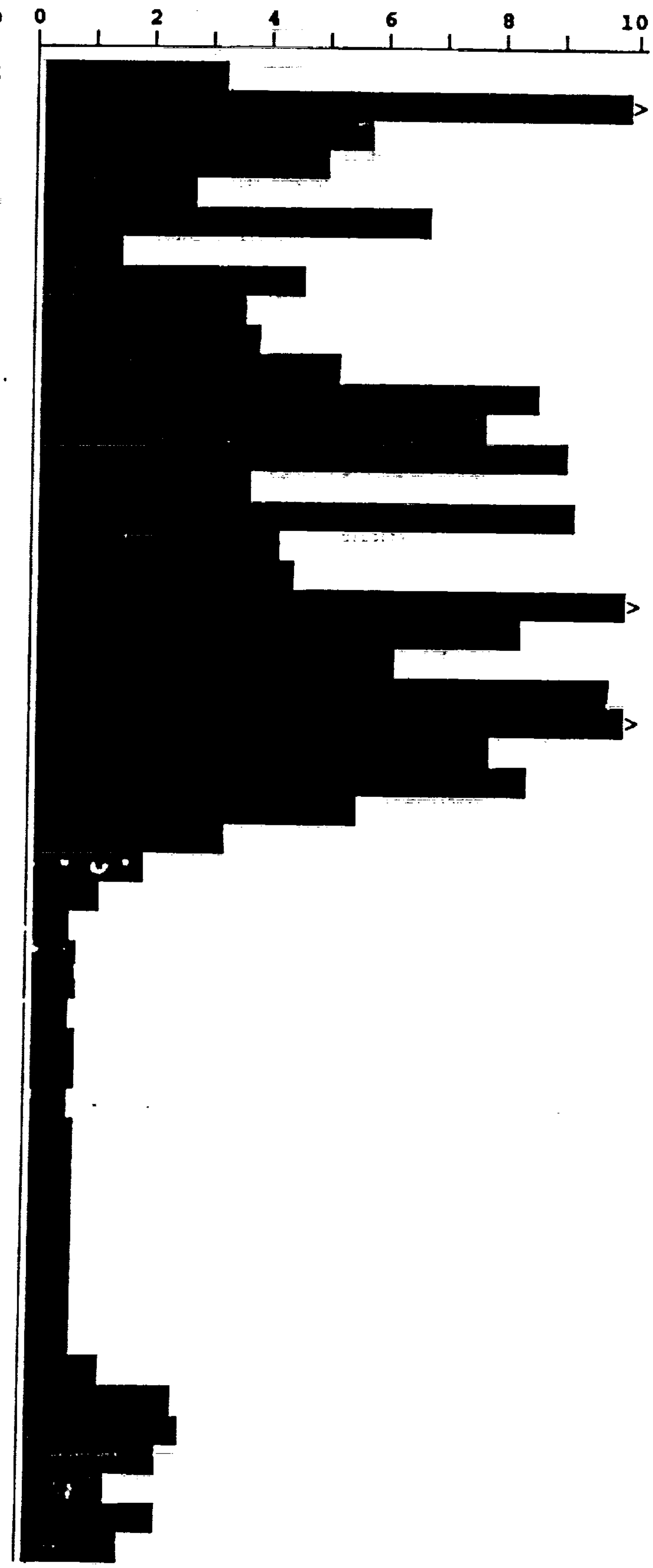
	FDDI	IEEE 802.3	IEEE 802.5
Bandwidth	100 Mb/s	10 Mb/s	4 or 16 Mb/s

Table 4. • Summary, comparison among standards

	FDDI	IEEE 802.3	IEEE 802.5
Logical topology	Dual ring, Dual ring of trees	Bus	Single ring
Physical topology	Ring, Star, Hierarchical star	Star, Bus, Hierarchical star	Ring, Star
Media	Optical fiber	Optical fiber, Twisted-pair, Coaxial cable, Microwave	Twisted-pair, Optical fiber
Bandwidth	100 Mb/s	10 Mb/s	4 or 16 Mb/s
Media access	Timed-token passing	CSMA/CD	Token passing
Token acquisition	By absorption	Not applicable (CSMA/CD)	By setting a status bit, converts token into a frame
Token release	After transmit	Not applicable (CSMA/CD)	After receive (4) or after transmit (16)
Messages on LAN	Multiple	Single	1 (4 Mb/s rings) multiple (16 Mb/s rings
Maximum frame size	4,500 bytes	1,518 bytes	4,500 bytes (4) 18,000 bytes (16)
Encoding Method	4B/5B NRZ/NRZI	Manchester	Differential Manchester
Number nodes	500	1024	260
Distance between nodes	2 km (1.2 mi)	2.8 km (1.7 mi)	300 m (984 ft) station to wiring closet (4 Mb/s ring), however, 100 m (330 ft) is recommended for both 4 and 16 Mb/s
Maximum network span	100 km (62 mi)	2.8 km (1.7 mi)	Varies with configuration

Appendix

	Time	%Usage
00	Jun 05 13:06:03	3.06
~~99~~	12:51:03	11.03
98	12:36:03	5.52
97	12:21:03	4.79
96	12:06:03	2.58
95	11:51:03	6.52
94	11:36:03	1.27
93	11:21:03	4.38
92	11:06:03	3.41
91	10:51:03	3.66
90	10:36:03	5.07
89	10:21:03	8.38
88	10:06:03	7.61
87	09:51:03	8.99
86	09:36:03	3.52
85	09:21:03	9.07
84	09:06:03	4.07
83	08:51:03	4.31
82	08:36:03	12.89
81	08:21:03	8.16
80	08:06:03	6.09
79	07:51:03	9.72
78	07:36:03	11.25
77	07:21:03	7.75
76	07:06:03	8.27
75	06:51:03	5.46
74	06:36:03	3.13
73	06:21:03	1.86
72	06:06:03	1.03
71	05:51:03	0.62
70	05:36:03	0.63
69	05:21:03	0.66
68	05:06:03	0.62
67	04:51:03	0.67
66	04:36:03	0.63
65	04:21:03	0.61
64	04:06:03	0.63
63	03:51:03	0.68
62	03:36:03	0.67
61	03:21:03	0.65
60	03:06:03	0.65
59	02:51:03	0.69
58	02:36:03	0.69
57	02:21:03	0.69
56	02:06:03	1.21
55	01:51:03	2.49
54	01:36:03	2.54
53	01:21:03	2.13
52	01:06:03	1.32
51	00:51:03	2.13
50	00:36:03	1.59



49	Jun 05 00:21:03	1.19
48	00:06:03	0.93
47	Jun 04 23:51:03	1.02
46	23:36:03	1.24
45	23:21:03	1.05
44	23:06:03	3.26
43	22:51:03	3.33
42	22:36:03	4.16
41	22:21:03	2.51
40	22:06:03	3.86
39	21:51:03	4.38
38	21:36:03	4.48
37	21:21:03	4.24
36	21:06:03	3.29
35	20:51:03	2.23
34	20:36:03	3.01
33	20:21:03	2.63
32	20:06:03	4.46
31	19:51:03	5.04
30	19:36:03	5.65
29	19:21:03	5.42
28	19:06:03	5.08
27	18:51:03	4.02
26	18:36:03	3.38
25	18:21:03	3.85
24	18:06:03	1.64
23	17:51:03	0.95
22	17:36:03	1.85
21	17:21:03	2.53
20	17:06:03	1.18
19	16:51:03	2.71
18	16:36:03	4.16
17	16:21:03	5.40
16	16:06:03	4.02
15	15:51:03	8.03
14	15:36:03	3.84
13	15:21:03	4.01
12	15:06:03	4.46
11	14:51:03	4.38
10	14:36:03	2.55
9	14:21:03	5.34
8	14:06:03	3.28
7	13:51:03	2.55
6	13:36:03	2.95
5	13:21:03	3.16
4	13:06:03	3.36
3	12:51:03	3.86
2	12:36:03	8.28
1	12:21:03	5.28