N.D. MURRAY

INFORMATION NETWORK ARCHITECTURES

NASA/LARC

506-58-13

INFORMATION DATA SYSTEMS FOR ADVANCED AEROSPACE MISSIONS, SUCH AS SPACE STATION AND ITS CO-ORBITING PLATFORMS, ARE NEEDED THAT ARE EVOLVABLE, ADAPTIVE, AND FAULT TOLERANT. LOCAL AREA INFORMATION NETWORKS ARE CONSIDERED A MOST LIKELY TECHNOLOGY SOLUTION; ITS PRINCIPLE NEEDS ARE: 1) THAT INFORMATION FLOW BETWEEN DEVICES ON A NETWORK AND ITS CONTROL REQUIRES IMPROVEMENT, PARTICULARLY FOR MODERATELY OR TIGHTLY COUPLED HIGH PERFORMANCE PROCESSES; 2) THAT THE NETWORK SHOULD POSSESS FAULT TOLERANT PROPERTIES TO MEET SAFETY RELATED CRITICALITIES; AND 3) THAT HIGH PERFORMANCE (>100 MBPS) IS REQUIRED IF SPACE STATION IS TO HAVE AN INTEGRATED SYSTEM DATA NETWORK FORM WHERE VIDEO, VOICE, AND DATA ARE TO BE SIMULTANEOUSLY ACCOMMODATED. THE BRAIDED MESH FORM OF NETWORK HELPS MEET THESE NEEDS WITH THE FOLLOWING FEATURES: 1) SIMULTANEOUS ADAPTABLE DATA COMMUNICATION LINKS OFFERS DYNAMIC AND HIGH PERFORMANCE ACCOMMODATION, AND 2) ALTERNATE COMMUNICATION LINKS PROVIDE A CAPABILITY FOR SELF-CORRECTING AND REPAIRING (OR FAULT TOLERANT) PROPERTIES. ALSO, THE HIGH PERFORMANCE REQUIREMENT LEADS TO THE CONCEPT OF A NETWORK THAT USES FIBER OPTICS LINKS AND OPTICAL NODES; FIBER OPTICS WITH WAVELENGTH DIVISION MULTIPLEXING WOULD BE USED.

THIS EFFORT IS TO RESEARCH AND CHARACTERIZE THE ARCHITECTURAL ISSUES OF THE BRAIDED MESH FORM OF NETWORK, AND ALSO TO DEVELOP AN OPTICAL NODE WHICH WOULD FORM THE USER INTERFACE INTO THE NETWORK, CONTROL USER ACCESS TO THE NETWORK, PROVIDE ADAPTABLE MULTIPLE PATH DATA COMMUNICATIONS FROM/TO OTHER NODES, AND PROVIDE FOR OVERALL CONTROL OF THE NETWORK. SUCH A NODE NEEDS A MEANS OF LOW LOSS OPTICAL SWITCHING, WHICH IS CURRENTLY BEING DEVELOPED THROUGH INTEGRATED OPTICS. FUTURE EFFORTS WOULD BE TO CONSTRUCT A LABORATORY HIGH PERFORMANCE NETWORK, POPULATE IT WITH HIGH PERFORMANCE NETWORK USER DEVICES, AND EVALUATE/CHARACTERIZE THE NETWORK.

INFORMATION NETWORK ARCHITECTURES

506-58-13/N. MURRAY

OBJECTIVE

INFORMATION NETWORK ARCHITECTURE - RESEARCH AND DEVELOP INFORMATION NETWORKS TO MEET THE SPACE STATION NEEDS OF SELF-CORRECTING AND REPAIRING, HIGH PERFORMANCE, EVOLVABILITY, ADAPTABILITY, SECURITY, AND EFFICIENCY.

APPROACH

- RESEARCH, EVALUATE AND CHARACTERIZE THE ARCHITECTURAL TYPE NETWORKS.
  - CENTRAL CONTROL, STATIC, SELF CORRECTING/REPAIRING (MESH)
  - DISTRIBUTED CONTROL, ADAPTIVE, SELF CORRECTING/REPAIRING (MESH)

    C. S. DRAPER LABS
    RTI/NORTH CAROLINA STATE UNIVERSITY
    UNIVERSITY OF ILLINOIS, URBANNA
    } IN-HOUSE EMULATION

- RESEARCH AND DEVELOP AN ADAPTIVE OPTIC NODE:
  - OPTIC X-SWITCH TEST ARTICLE — BATTELLE MEMORIAL INST.
  - INTERMEDIATE OPTIC NODE — HONEYWELL INC.
  - FINAL OPTIC NODE
- RESEARCH, EVALUATE AND CHARACTERIZE A HIGH PERFORMANCE, ADAPTIVE, OPTICAL NODE TYPE NETWORK. (FOCUSED TECHNOLOGY PROPOSAL)

MANNED SPACE STATION

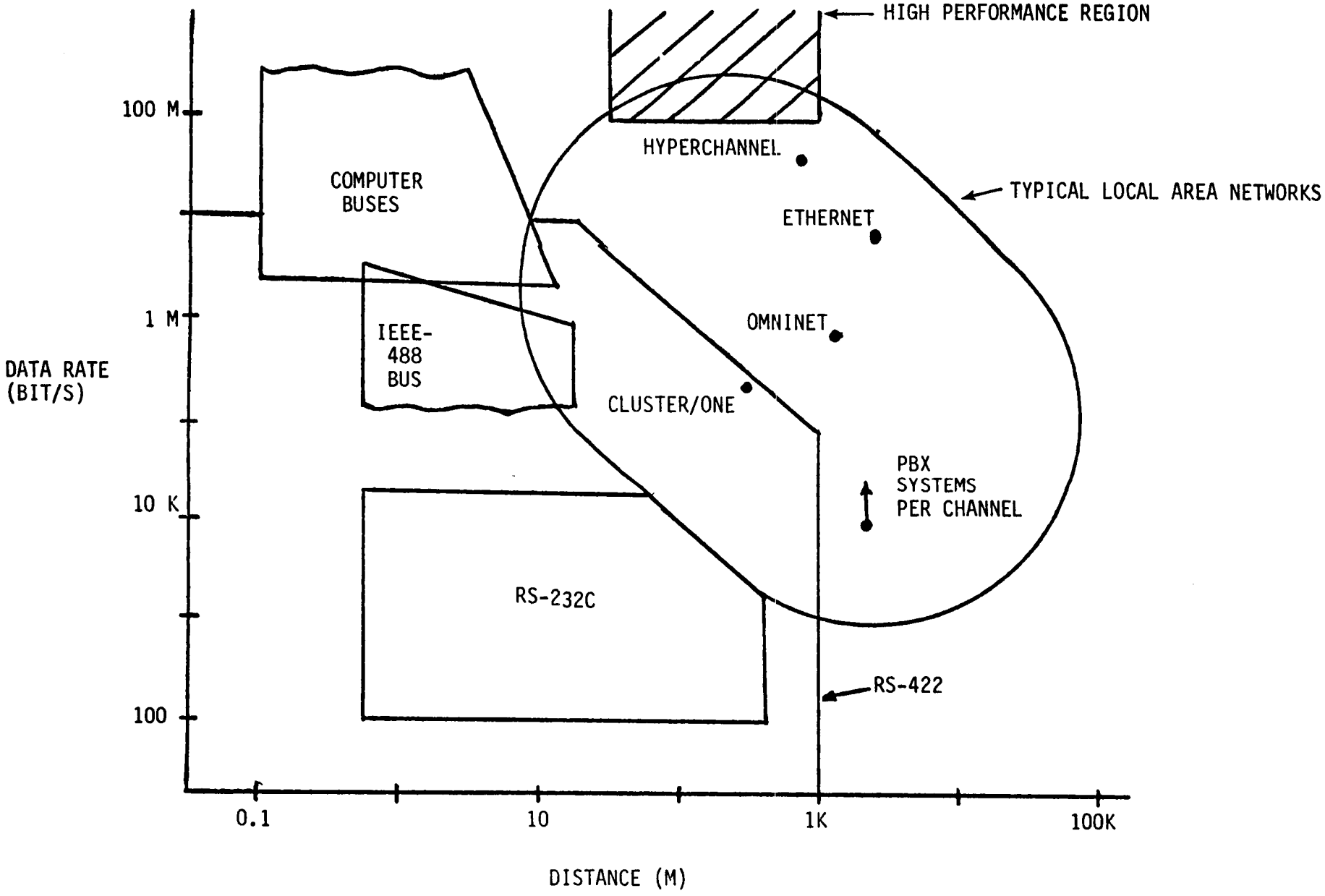
REQUIREMENTS FOR INFORMATION PROCESSING	CRITICALITY	PERFORMANCE
1. EXPERIMENTS AND MANUFACTURING	HIGH	MODERATE
2. OBSERVATIONS	HIGH	HIGH
o EARTH o NEAR EARTH o SOLAR SYSTEM o DEEP SPACE		
3. COMMUNICATIONS	HIGH	MODERATE
4. CONSTRUCTION	HIGHER	HIGH
5. STABILITY AND CONTROL	HIGHEST	MODERATE
6. AUTONOMY/AUTOMAINTENANCE	HIGHEST	MODERATE
7. HOUSEKEEPING	HIGHEST	MODERATE

CRITICALITY - HIGHEST IMPLIES MAN RATED OR SPACECRAFT RATED SAFETY.
HIGH IMPLIES HIGH COST BUT NOT SAFETY RELATED.

PERFORMANCE - COMMUNICATION ● MODERATE ~ 50 MBPS ● HIGH > 100 MBPS PROCESSING ● MODERATE ~ 10 MOPS ● HIGH > 50 MOPS

SUMMARY CHARACTERISTICS OF DATA TRAFFIC SOURCES

TRAFFIC TYPE	NDM, MESSAGE LENGTH (BITS)	RATE BPS	CALL GEN. RATE	HOLDING TIME	DELAY REQUIRE.
STREAM VOICE	CONTINUOUS	64K	LOW	LONG	ALMOST INSTANTANEOUS
STREAM DATA	CONTINUOUS	64K	LOW	LONG	VARIABLE
INTERACTIVE DATA	HUNDREDS TO THOUSANDS	64K	HIGH	SHORT	FRACTION SEC. TO SECONDS
INQUIRY/ RESPONSE DATA	HUNDREDS TO THOUSANDS	64K	LOW	SHORT	SECONDS TO MINUTES
DATA BASE UPDATE	HUNDREDS	TBD	LOW	SHORT	SECONDS TO MINUTES
BULK DATE TRANSFER	GREATER THAN 10^4	TBD	LOW	MED TO LONG	SECONDS TO HOURS
DIGITAL VIDEO	CONTINUOUS	100M	LOW	LONG	ALMOST INSTANTANEOUS


HIGH PERFORMANCE REGION
HYPERCHANNEL
TYPICAL LOCAL AREA NETWORKS
ETHERNET
OMNINET
CLUSTER/ONE
PBX
SYSTEMS
PER CHANNEL
COMPUTER
BUSES
IEEE-
488
BUS
RS-232C
RS-422
100 M
1 M
10 K
100
DATA RATE
(BIT/S)
0.1
10
1K
100K
DISTANCE (M)

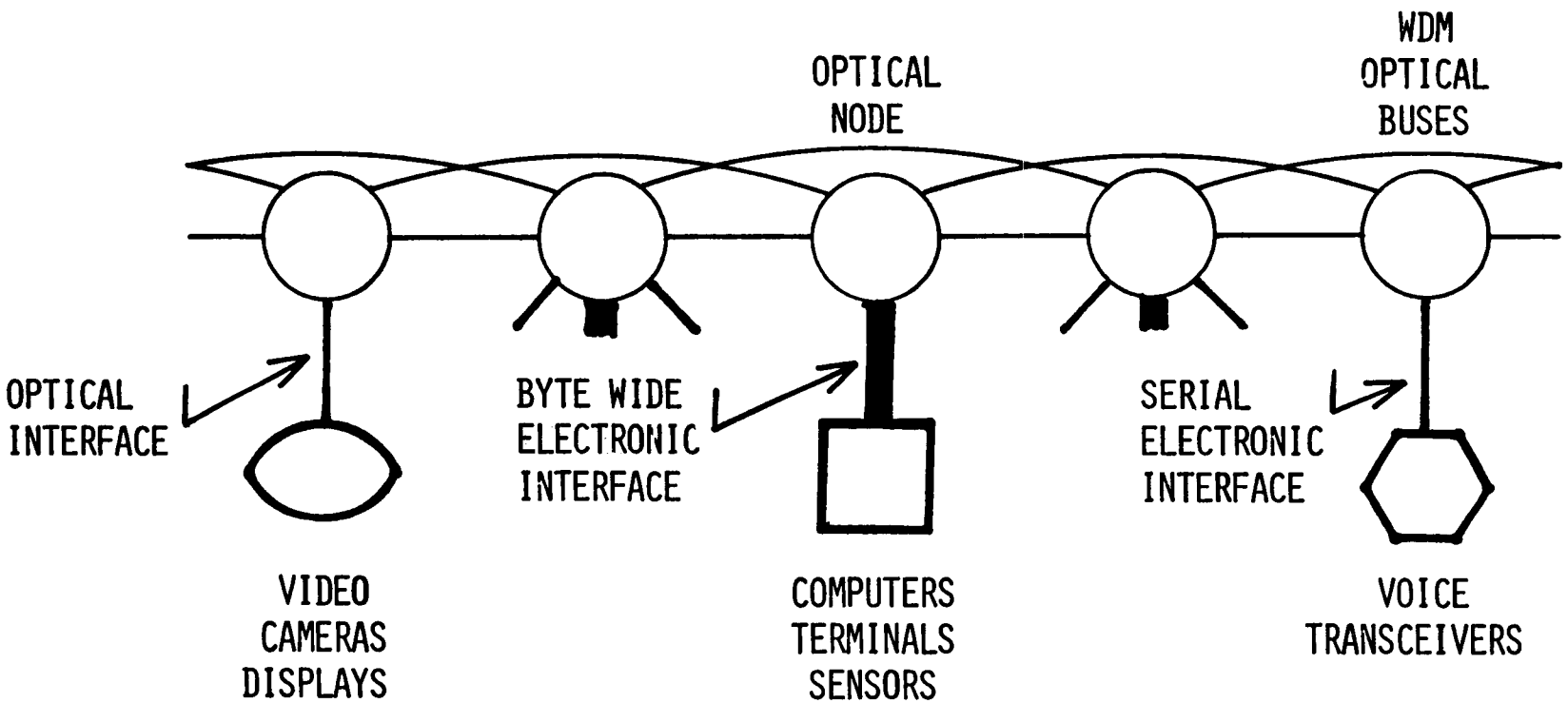
INFORMATION NETWORK ARCHITECTURES

506-58-13/N. MURRAY

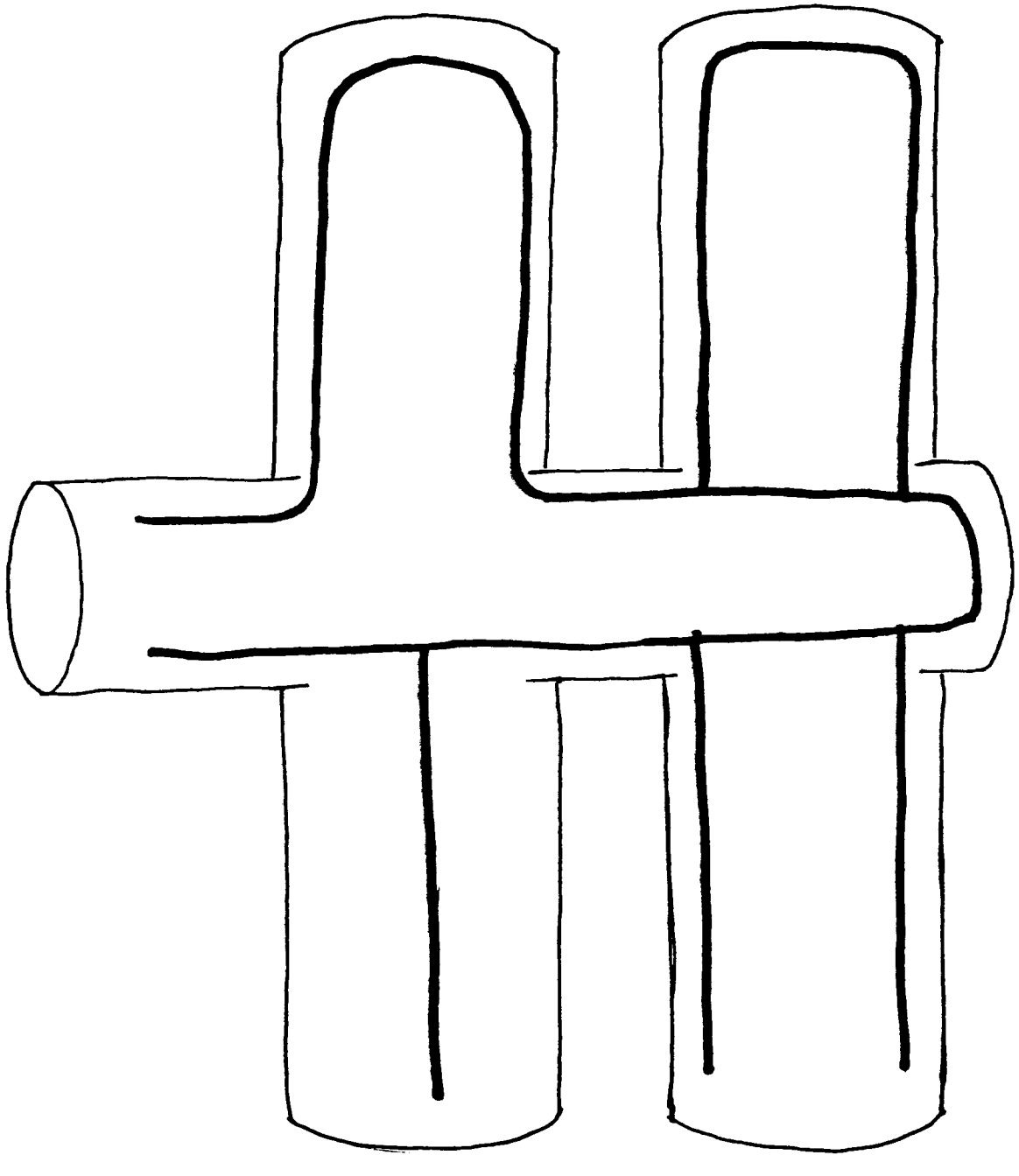
- INTEGRATED - DATA, VOICE, VIDEO
- KEY ISSUES OF NETWORKS
  - INFORMATION FLOW/OPERATING SYSTEM (SEPARATE DATA, CONTROL COMMUNICATIONS)
  - SELF-CORRECTING AND REPAIRING/FAULT TOLERANCE (MESH TOPOLOGY)
  - HIGH PERFORMANCE (FIBER OPTICS/INTEGRATED OPTICS, MESH TOPOLOGY)

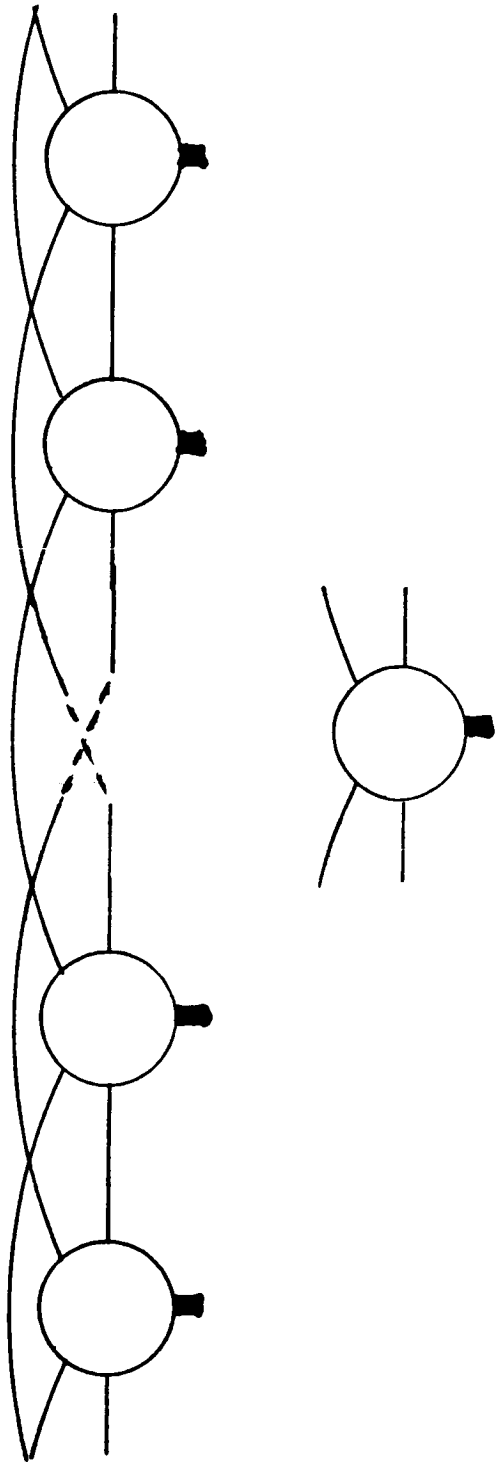
INFORMATION FLOW BETWEEN COMPUTERS AND OTHER DEVICES REQUIRES A SYSTEM AND ARCHITECTURAL SOLUTION THAT AFFECTS BOTH HARDWARE AND SOFTWARE. CURRENT SYSTEMS USE EXTENSIVE SOFTWARE FOR THE INFORMATION FLOW RESULTING IN A SOFTWARE BOTTLENECK; CONTROL ALGORITHMS AND METHODS FOR TIGHTLY COUPLED, HIGH PERFORMANCE, DISTRIBUTED PROCESSING ARE INADEQUATE; SELF CORRECTING AND REPAIRING TECHNIQUES ARE NOT BEING FULLY APPLIED TO TODAY'S SYSTEMS. REAL-TIME, FULL MOTION, DIGITAL COLOR VIDEO REQUIRES DATA RATES IN EXCESS OF 100 MBPS.

NETWORK ARCHITECTURE/TOPOLOGY

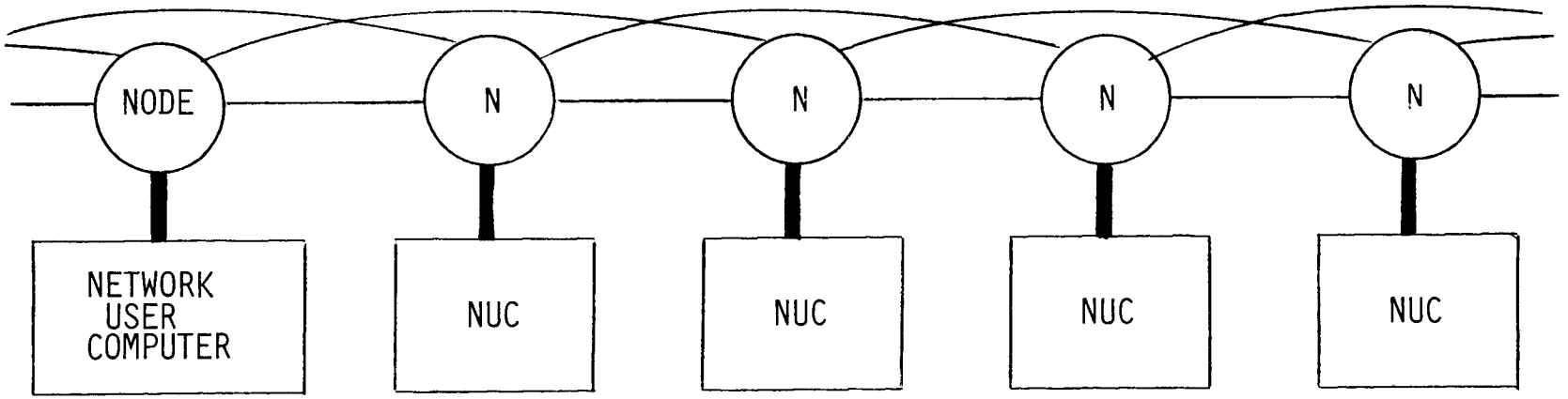


- HIGH PERFORMANCE
- FAULT TOLERANT





ELECTRONIC EMULATION OF OPTIC NETWORK

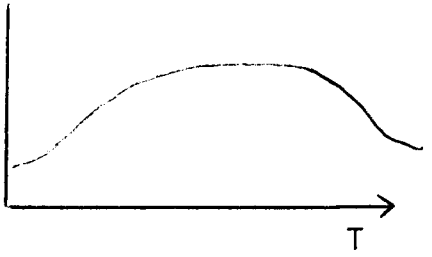


DATA ACCUMULATION
- EVENTS
- TIME

STATISTICAL EVALUATIONS

USER SERVICE DEMAND

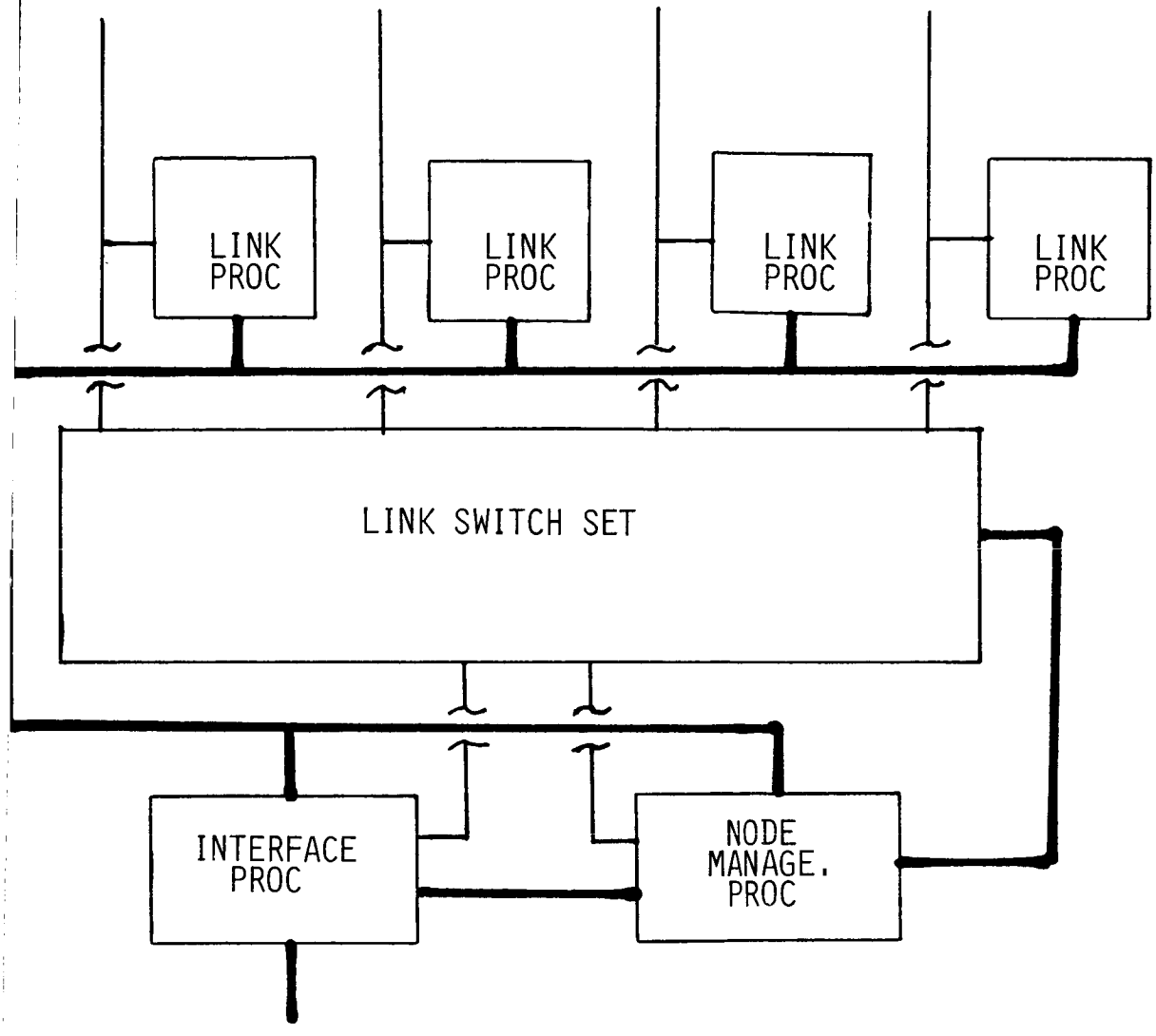
USER SERVICE TIME



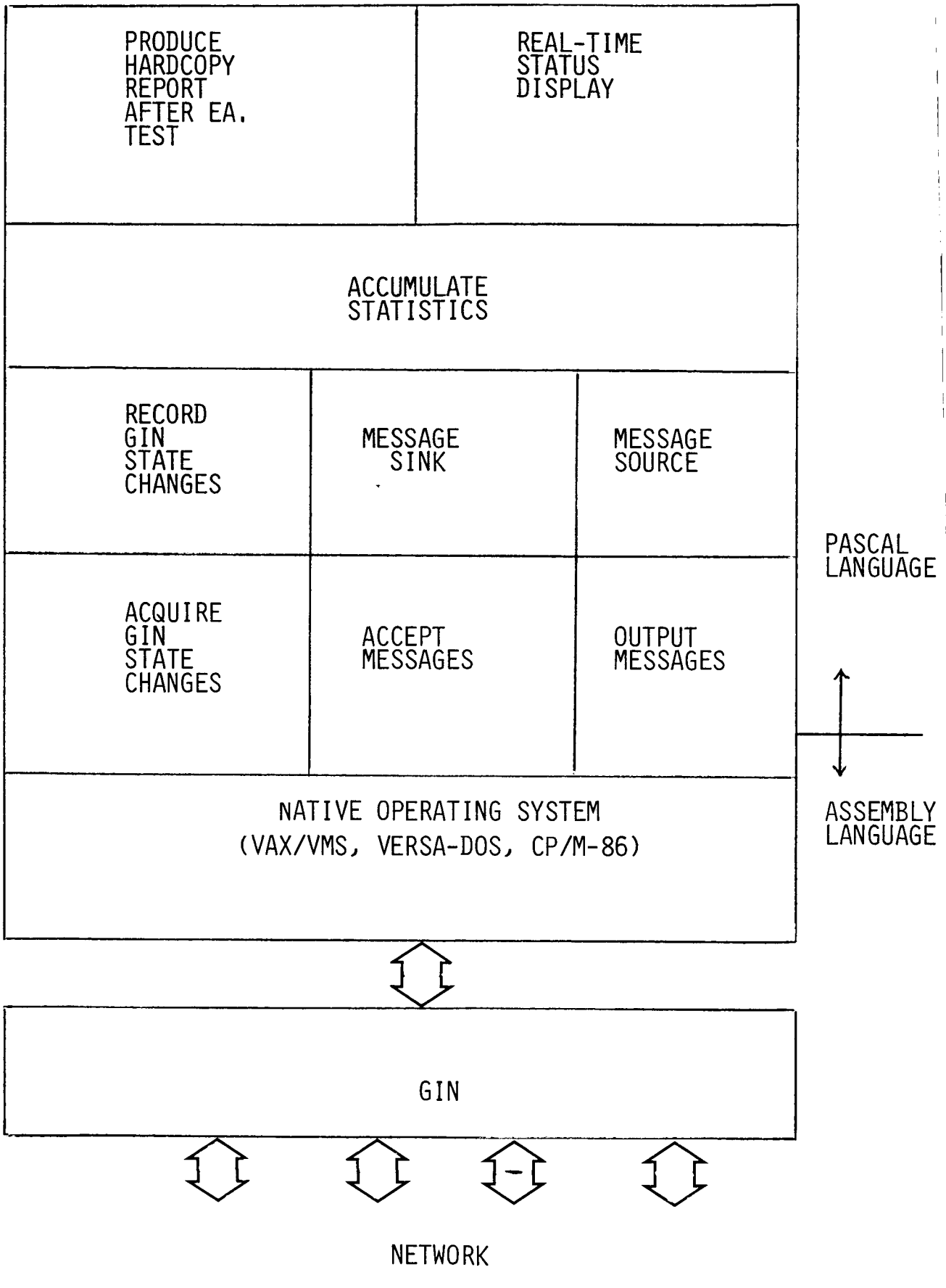
PARAMETRICALLY CONTROLLED DISTRIBUTIONS

EVALUATION OF:
- FAILURE DETECT/ RECOVER
- CENTRALIZED ROUTING
- DISTRIBUTED ROUTING
- FLOW CONTROL
- NETWORK UTILIZATION
- NUC/NODE INTERFACES

EMULATION NODES



ALL PROCESSORS MOTOROLA M68K


PRODUCE HARDCOPY REPORT AFTER EA. TEST
REAL-TIME STATUS DISPLAY
ACCUMULATE STATISTICS
RECORD GIN STATE CHANGES
MESSAGE SINK
MESSAGE SOURCE
ACQUIRE GIN STATE CHANGES
ACCEPT MESSAGES
OUTPUT MESSAGES
PASCAL LANGUAGE
ASSEMBLY LANGUAGE
NATIVE OPERATING SYSTEM
(VAX/VMS, VERSA-DOS, CP/M-86)
GIN
NETWORK

ROUTING ALGORITHMS

1) NON-ADAPTIVE

- NO ATTEMPT TO ADJUST TO CHANGING NET CONDITIONS
- FIXED OR RANDOM ROUTING

2) CENTRALIZED ADAPTIVE

- CENTRAL AUTHORITY DICTATES ROUTING DECISIONS
- MORE NEAR OPTIMAL ROUTING
- ROUTING CONTROL CENTER CAN REPRESENT PERFORMANCE BOTTLENECK

3) ISOLATED ADAPTIVE

- INDEPENDENT OPERATION
- ADAPTABILITY VIA EXCLUSIVE USE OF LOCAL NODE DATA

4) DISTRIBUTED ADAPTIVE

- UTILIZE INTERNODE COOPERATION
- NODES EXCHANGE INFORMATION TO ARRIVE AT ROUTING DECISIONS

-McQUILLAN, BBN

PATH SEARCH ALGORITHM

Purpose

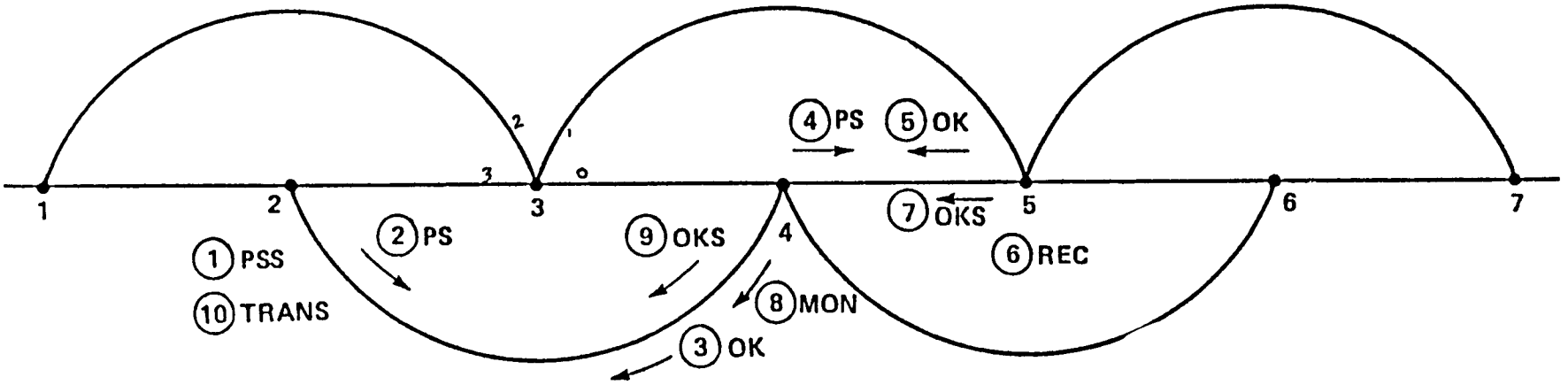
1. Routing data through a meshed network
2. Establishing a circuit set up
3. Adaptive to topological changes
4. Simultaneous communication desirable

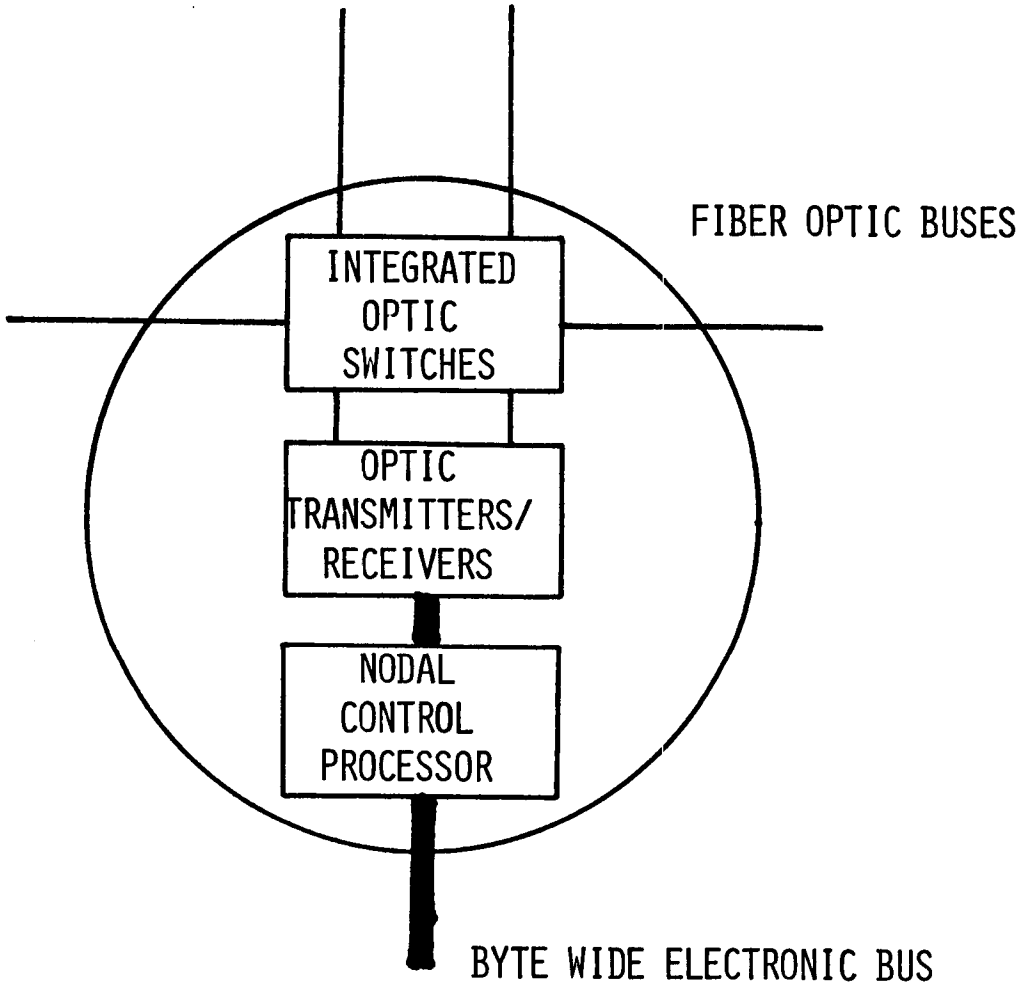
ROUTING ALGORITHM

Example: for node 3

Link Priority	DESTINATION NODE 1	2	3	4	5,6,7
1	LP 2 → 1	LP 3 → 2	—	LP 0 → 4	LP 1 → 5
2	LP 3 → 2	LP 2 → 1	—	LP 1 → 5	LP 0 → 4
3	LP 0 → 4	LP 0 → 4	—	LP 3 → 2	LP 3 → 2
4	LP 1 → 5	LP 1 → 5	—	LP 2 → 1	LP 2 → 1

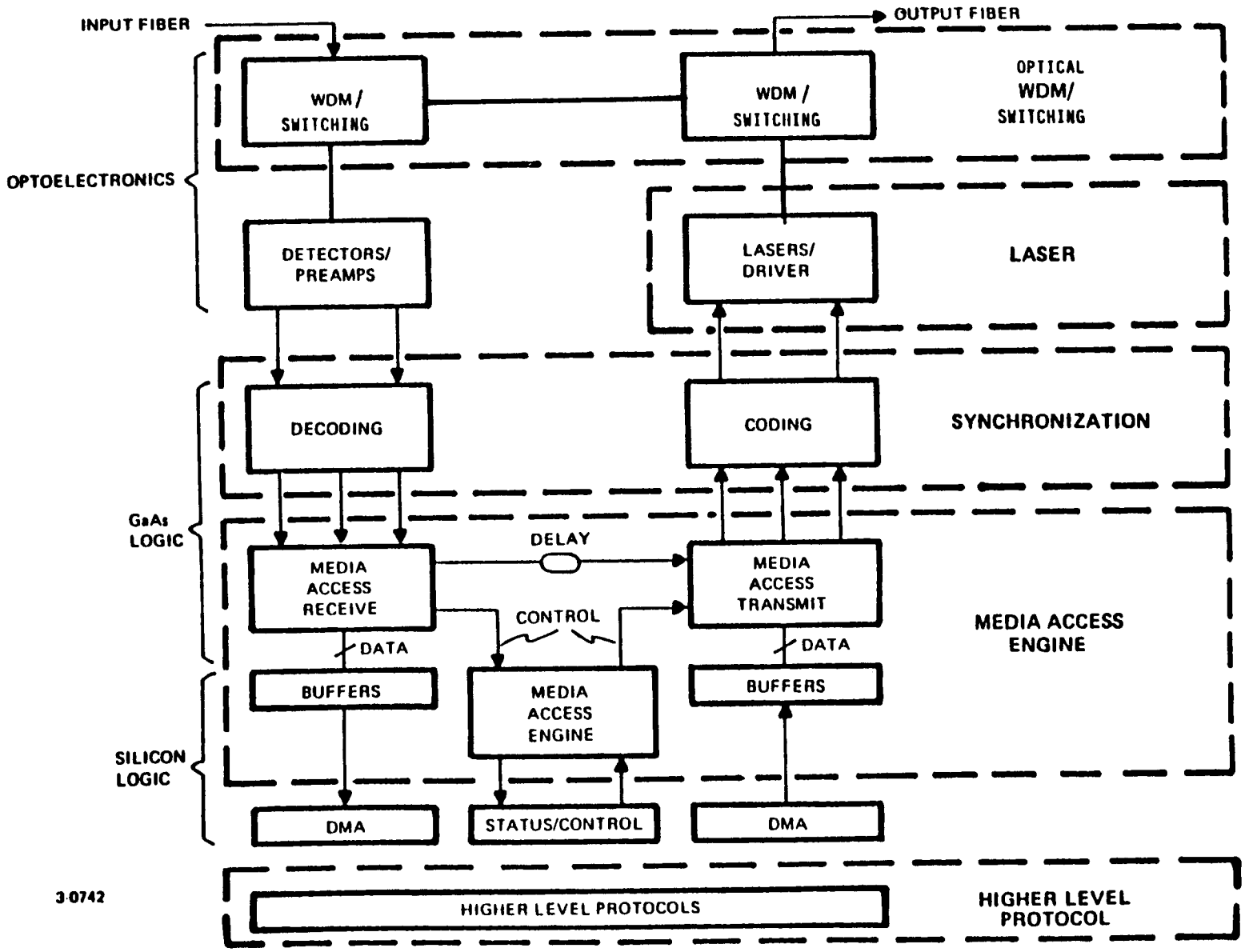
EX 1: NORMAL OPERATION





ADAPTIVE NODE DEFINITION

TECHNOLOGY PARTITIONING OF NODE INTERFACE UNIT

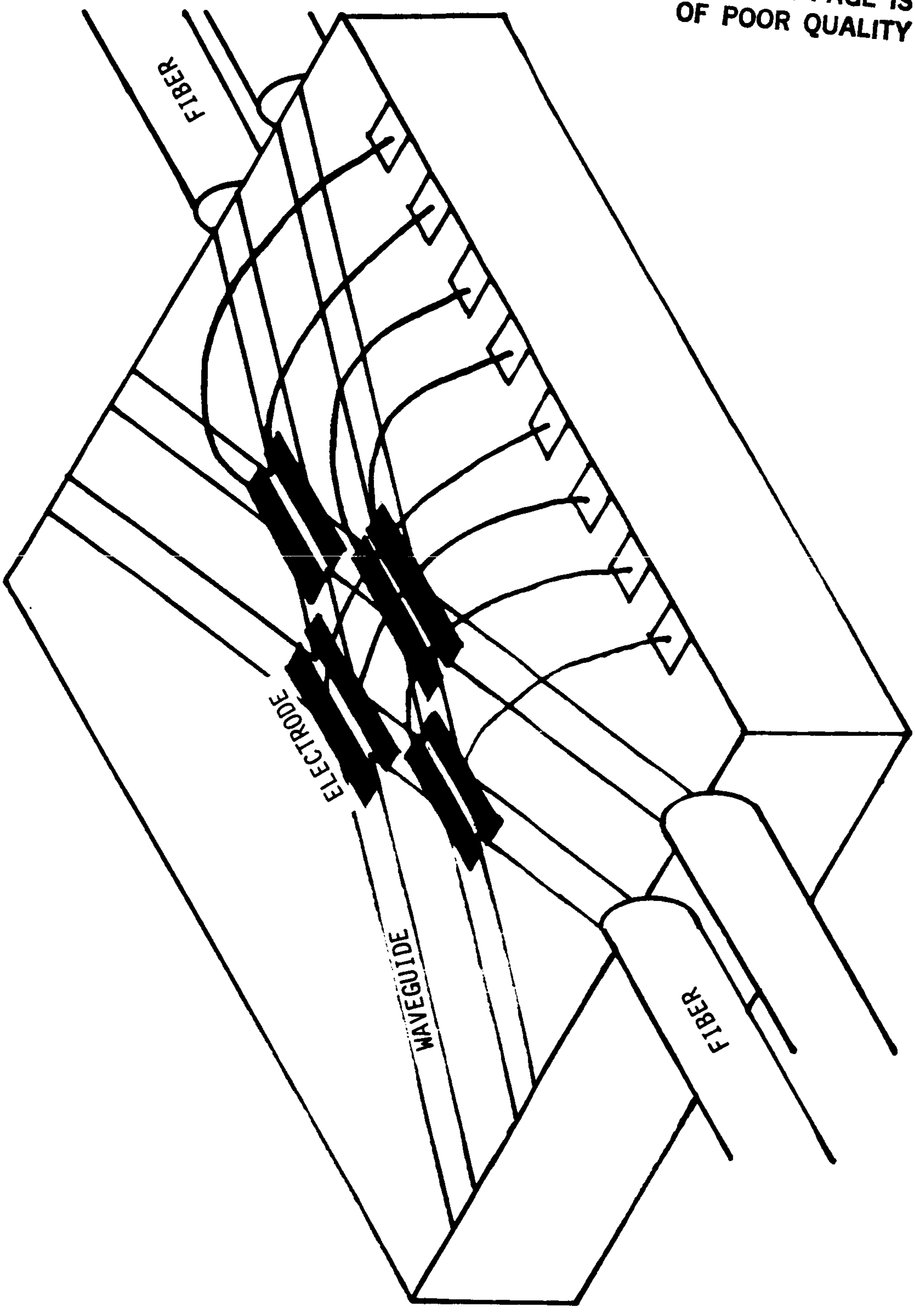


INTELLIGENT OPTIC NODE TECHNOLOGY TIMELINE

FUNCTIONS \ TIME	NEAR TERM (1-2 YEARS)	MEDIUM TERM (3-5 YEARS)	LONG TERM (5-10 YEARS)
• E/O	GaAlAs (discrete)	GaAlAs with drive/ detector electronics	Monolithic GaAs
• O/E	Si		
• Fiber	Single mode, non-polarization preserving		polarization preserving?
• Taps, Delay	Fiber	SAW	TBD
• Amplification	Si	GaAs	Monolithic GaAs
• Switching	$LiNbO_3$ (bulk)	$LiNbO_3$ / ZnO ?	ZnO? / ALGaAs
• Synchronization	Si / GaAs	GaAs (discrete)	Monolithic GaAs
• Frame/Address Recognition	Fiber / GaAs	SAW / GaAs	TBD
• Conflict Resolution	Si / GaAs	GaAs	Monolithic GaAs
• Routing	N/A	Si / GaAs (di[redacted]	
• Higher Level Protocols		Si	

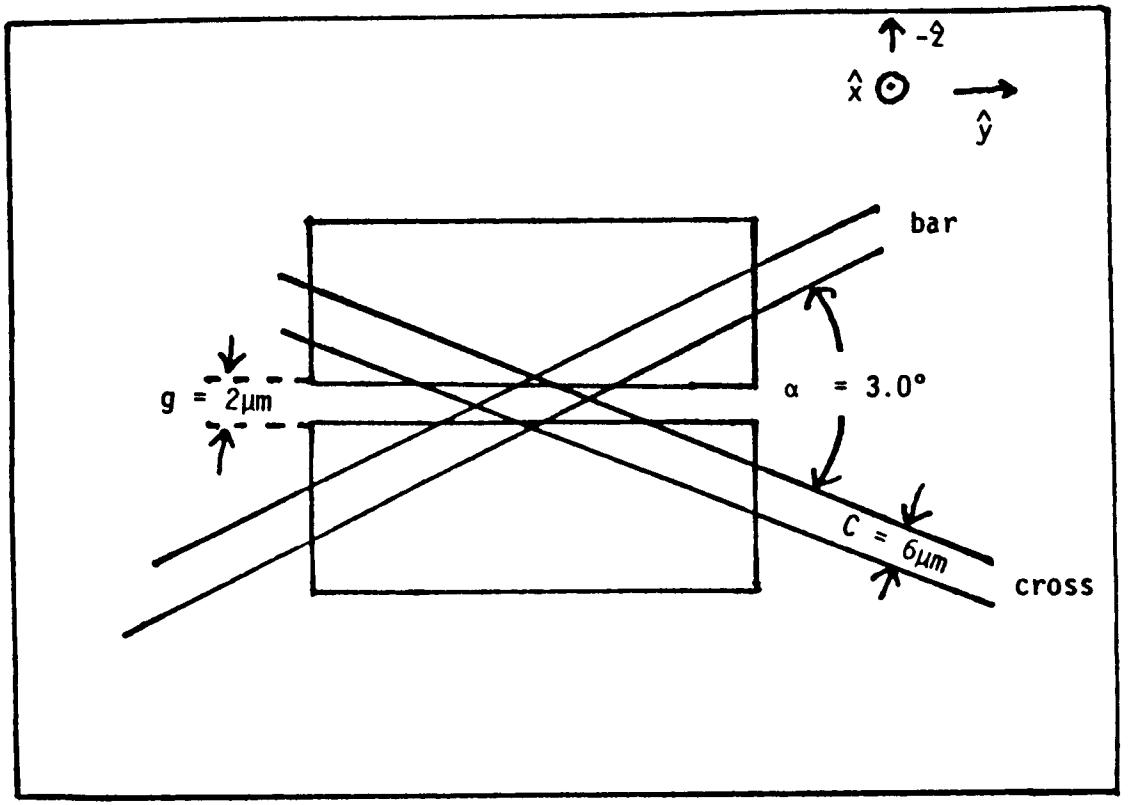
SOURCE MATERIALS

MATERIALS	GaAs/GaAlAs	InGaAsP	AlInGaAs	InGaAs	GaN	GaAsP
EMISSION WAVELENGTH	.82-.9 μm	1.0-1.6 μm	1.0-20 μm	3.3-3.8	.4 μm	VISIBLE
LASERS	X	X	X	NO	NO	NO?
LED's	X	X	X	X	X?	X
INTEGRATABLE	YES	YES	YES		NO	NO
WITH ELECTRONICS	GaAs	InPor InGaAs (LOW LEVEL)			NO	NO
EASE OF FABRICATION	MATURE	ALMOST MATURE LPE GROWTH	EXPERIMENTAL MBE/MOLVD	NEXT TO IMPOSSIBLE LPE	CONCEPTUAL	MATURE VPE



SCHEMATIC OF 2 x 2 SINGLE-MODE SWITCH

OPTICAL SWITCH DEVELOPMENT



Voltage	bar	cross
0 volts	40	60
+40 volts ($-\hat{z}$ is +)	90	10
-20 volts	10	90
-40 volts	40	60

X-SWITCH LOSS ESTIMATES

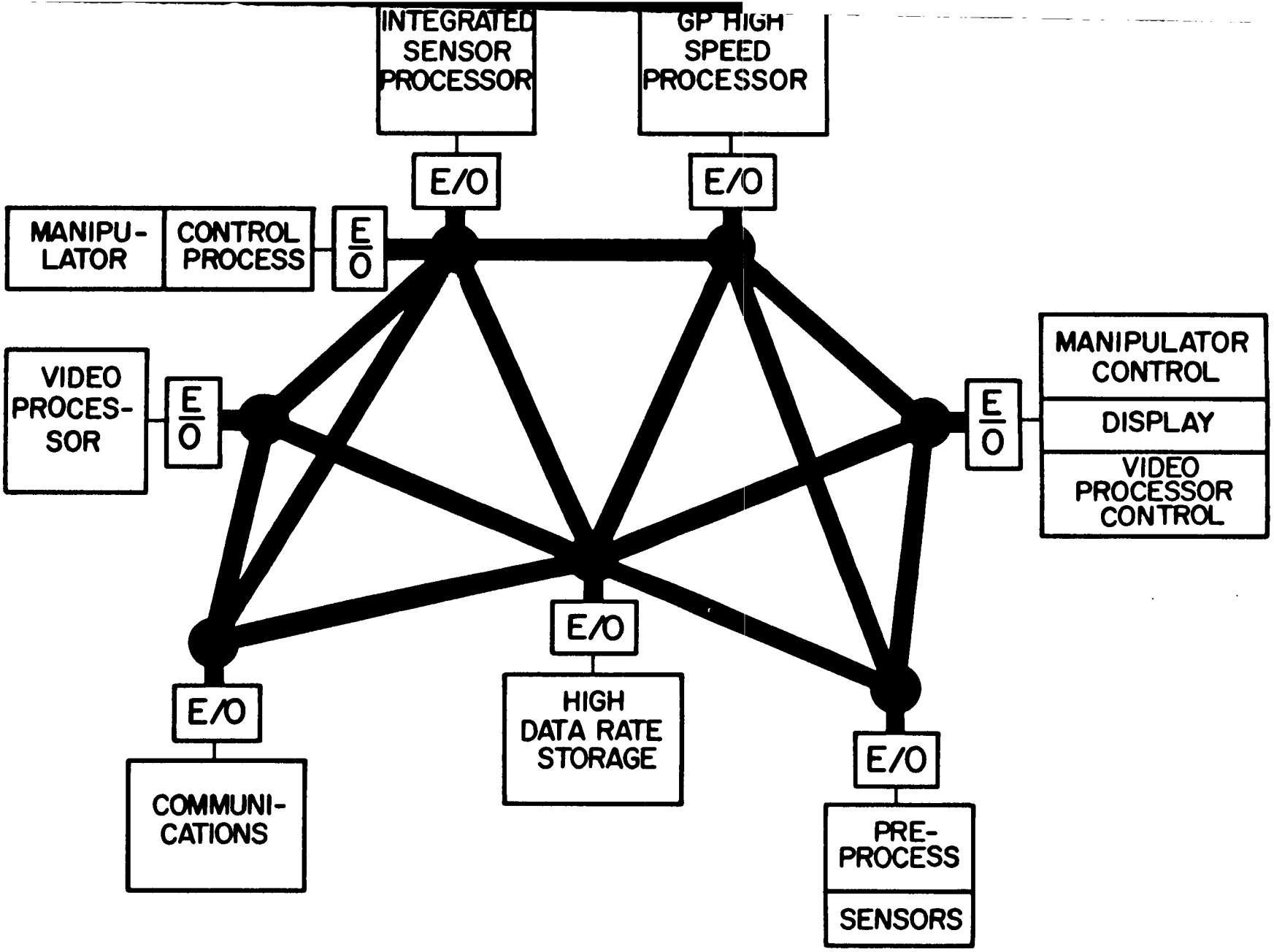
	POLARIZATION PRESERVING FIBER	SINGLE MODE FIBER	MULTI MODE FIBER
INPUT	0.5	3.5	?
CROSS(1)	0.1	0.1	0.1
BAR(2)	0.2(3)	0.2(3)	0.2(3)
WAVEGUIDE	0.5	0.5	0.5
OUTPUT	0.5	0.5	0.5
TOTAL	1.8 DB	4.8 DB	1.3 + X(4)

(1) A SWITCH IN CROSS STATE
(2) A SWITCH IN THE BAR STATE
(3) TOTAL EXCESS LOSS
(4) X IS UNBOUNDED; COULD BE TIME DEPENDENT

COMMON FEATURES FOR ALTERNATIVE DISTRIBUTED OPTICAL SWITCHING ARCHITECTURES

	FUNCTIONS \ ARCHITECTURE	LINEAR/STAR BUS	RING BUS	CIRCUIT SWITCH MESH	PACKE SWITC MESH
PHYSICAL LAYER	TRANSMITTER/ RECEIVER	BURST ASYNC	SYNCHRONOUS	BURST ASYNC	
	SWITCH	NO			
	COUPLER				
	CHANNELIZATION (WDMUX-WDDMUX)				
	AMPLIFIER		COMMON FEATURES		
	DELAY				
DATA LINK	ADDRESS COMPARE				
	CONFLICT RESOLUTION			SLOW	FAST
	ROUTING/GATEWAY				
HIGH LEVEL PROTOCOL	HI LEVEL PROTOCOL	RING OR STAR COMMON.		MINIMAL	SIMILAR TO RING OR STAR

TABLE (1)



[EXAMPLE HIGH PERFORMANCE NETWORK]