3rd PROMETHEUS Workshop
Turin 26./27.04.1990
S. 408 - 419

COMBINE: A Modular System for Communication with Identification and Localization

T. Hellmich, H.-J. Perz, C.-H. Rokitansky, B. Walke, W. Zhu
Dataprocessing Techniques
Dept. Electrical & Electronics Engineering
FernUniversity of Hagen, D-5860 Iserlohn, West Germany

Abstract:
Equipment for a short-range radio communication network is described covering the demands of any communication related PROMETHEUS Functions defined so far. One important feature is integration of vehicle-to-vehicle and vehicle-to-infrastructure communication into one network, thereby minimizing the need for protocol conversion between the short-range radio and any connected long-range infrastructural communication networks to the smallest degree possible. A second attractive property is integration of communication, identification and relative localization into one system such that the highest possible spectrum efficiency is reached. A third nice feature is the ability to configure the equipment properly to serve just these PROMETHEUS Functions being of importance to some user group aimed at. Thereby, the system proves to be highly cost efficient. Our proposal is based on careful analytic and simulative analysis, being still under way, to secure the functionality of the newly developed lower layer protocols. The higher layer protocols are based on widely used standard protocols and cover any services known from computer communication networks. A phase concept for early field trials and an Europe-wide field trial based on amateur packet radio is described.

1. INTRODUCTION

To date, the PROMETHEUS Functions are not specified in sufficient detail, such that the related performance figures required from the radio communication network can be derived, definitively. What, however, can be defined are sets of applications requiring related performance attributes, which approach is useful to define well adapted options of the communication equipment for the respective purposes.

In what follows, three sets of applications are defined by means of commonly agreed PROMETHEUS Functions. For each set a well adapted communication equipment is defined, characterized by a seven layer protocol stack, differing mainly in the first two layers. Layer three is common to all type of equipment and is based on PROMETHEUS specific routing and addressing techniques.

Part of layer three and layers four to seven are proposed to use, at least during an introductory stage, the widely applied and well accepted INTERNET protocol stack, being a quasi standard through its worldwide use in computer communication networks. By adopting these protocols, an early functioning of PROMETHEUS equipment and its exploration during field trials becomes possible. Experiences gained from field trials are urgently needed to refine the operational requirements of the various applications, currently under consideration. It is part of this concept to replace such protocols by ISO/OSI and PROMETHEUS protocols, as soon as they will be available.

Layers 1 and 2 depend on the performance required for a given set of applications. All three options of the proposed equipment combine communication with identification and relative positioning and cover short-range communication between vehicles and to the infrastructure:

In **option A** packet-radio communication based on asynchronous multiple-access protocols for bursty traffic is supported. No protection against interference from hidden stations is provided and no maximum packet delay is guaranteed.

In **option B** multiple-access with reservation is provided. Due to a slotted radio channel and introduction of slot reservation, continuous communication is supported, besides single-packets. Stations must be locally synchronized with respect to the slot structure. Delay time for continuous mode communication is deterministic. However, no full protection against interference from hidden stations is provided.

Option C uses channel switched communication and techniques to guarantee interference free channel establishment, despite hidden stations. To further reduce interference from hidden stations, subframes are used to assign communications capacity according to the direction in which a vehicle moves. Compared to options A or B, highly reliable radio channels are provided supporting, besides others, efficient use of radio bandwidth and real time applications.

In section 2 the basic idea of combining communication with identification and relative positioning is introduced. In section 3 options A, B, and C are described in more detail. Section 4 describes the layer 3 functionality. More details on the INTERNET protocols recommended for layers 4 to 7 are found in section 5. A discussion of the gateway and internetting functions to interconnect short-and long-range networks is presented in section 6. Section 7 describes early field trials based on available communications equipment.

2. COMMUNICATION WITH IDENTIFICATION AND RELATIVE POSITIONING

The three options of the COMBINE system have in common the ability to combine the functions of communication via a short-range radio network with identification and relative positioning of the involved stations. Apparently, these additional functions might be switched off, leaving behind a normal communication equipment being useful to serve PROMETHEUS Functions like F15 and F16, needing no relative localization.

Transponder systems were claimed to be well suited for identification, relative positioning, and communication [FoGr 89], [HABHW 89]. Such systems apply multiple-access packet radio protocols like (S)-ALOHA, or CSMA to transmit a squitter signal in random time intervals containing a station's address, allowing other stations to interrogate and measure the propagation delay until a station's response. Such response is required to follow immediately an interrogation, using a separate frequency band.

We propose integration of the transponder function into the communication system. The system can then better be suited to communication, than is possible with the opposite approach, where the transponder is used for communication, too.

Instead of forcing an interrogated station to reply immediately, the reply is allowed to be transmitted after any suitable time delay, which length must be specified inside the response packet. This avoids a separated frequency band, normally required with transponders for responses. We assume that a delay of some (non)integer multiple of a communication packet length is tolerable before responding to an interrogation.

Further we assume that both, interrogation and response, are part of normal communication packets. In Fig. 2.1 a slotted time axis is shown, presuming slot synchronous communication between adjacent stations. Such local synchronization was shown to be possible [ZhWa89], but is not a prerequisite, since our proposal works also with asynchronous protocols. A sample of packet-radio communication between stations A and B is shown in Fig. 2.1, where packets are preceded by interrogation or response sequences, respectively, enabling the communication equipment to perform distance measurement.

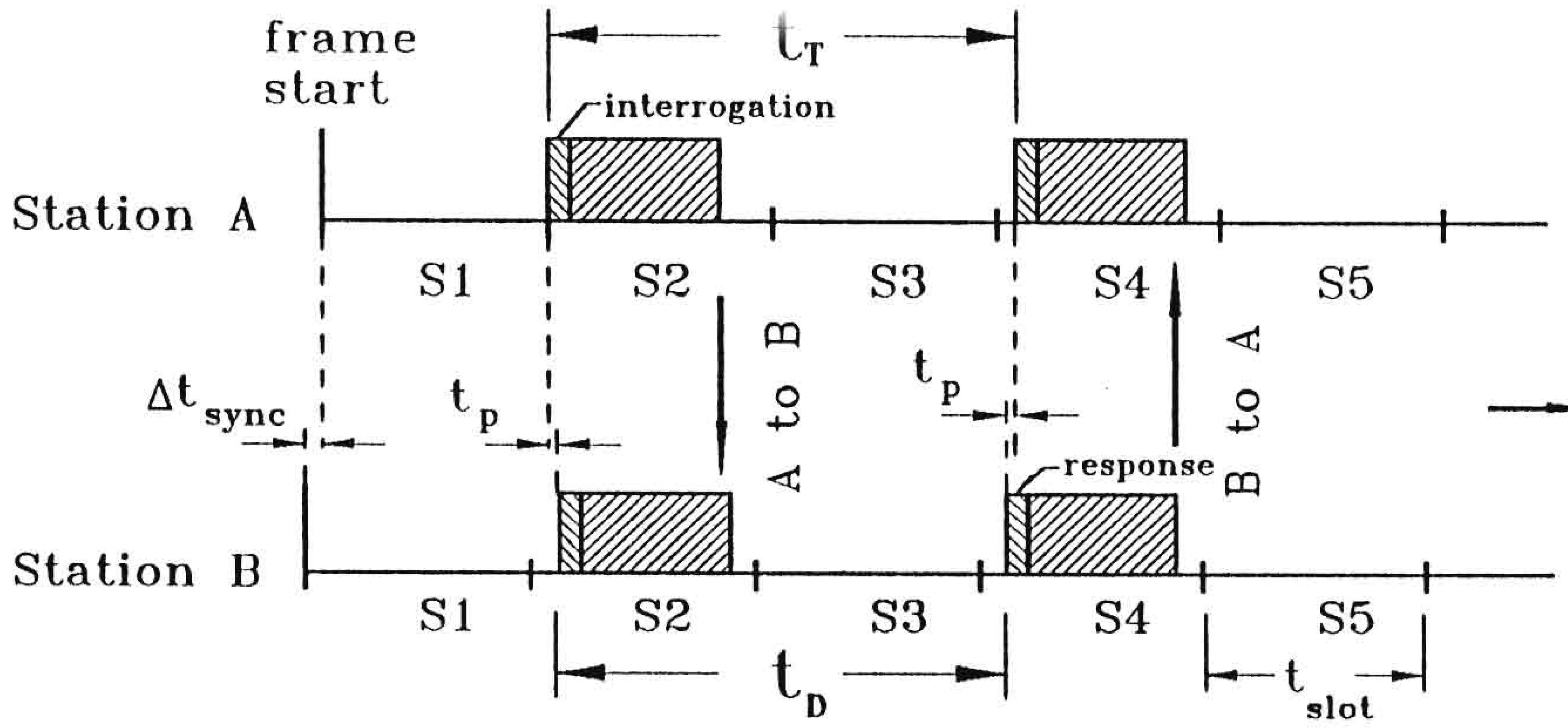

Fig. 2.1: Distance Measurement as Part of Communication in COMBINE

Stations transmit hello packets in random time intervals, if they don't hear each other. A transmitting station A, communicating point-to-point to station B includes the interrogation sequence in its packet. The packet is received at B after the propagation delay t_p. Station B sends its next packet not at the beginning of its slot, but after a time delay t_D, which is communicated in the packet, and includes the response sequence as a prefix. A is then able to compute the round trip delay $2t_p$ and will transmit its measurement result to B as part of the next packet. To increase reliability of distance measurement, interrogation is periodically altered between the two stations. Distance measurement is performed as long as the communication relationship exists. Addresses used for communication uniquely identify which stations are involved in distance measurement. Apparently, such mechanism would also work without a slotted time basis. For an introductory phase where no integrated communication and distance measurement equipment is available, we propose to use separated equipment, where the transponder is synchronized by the communication equipment to transmit its interrogation and response sequences.

3. OPTIONS OF THE COMBINE EQUIPMENT

In what follows, the three options of the COMBINE equipment mentioned are described in more detail. In particular, the improvements in accomplishing the requirements of PROMETHEUS communication Functions are emphazised.

3.1. Option A, Using Asynchronous Multiple-access Protocols

Option A is an early applicable system to serve communication, identification and localization, covering some demands of PROMETHEUS Functions F1, F2, F13, F14, F15, F16.

In the simplest version, the option contains only an asynchronously operating transponder system using two signals, one for interrogation and the other for reply purposes. If a station wants to know its distance from another station it transmits an interrogation. Any receiving station replies via a separate frequency band. The duration between interrogation and reply consists of the propagation delay and a fixed processing delay in the responding station. The only information available is the distance between two stations.

In the normal version of option A we assume the transponder system being able in addition to offer comunication capacity /FoGr 89/. Squitters are sent in random time intervals to identify a station to others through its address. Three signals are used: squitter, interrogation, and reply, each offering some capacity for information transfer. Addresses are used with these signals. The system covers distance measurement, identification and communication.

Characteristics of Option A	
Layer 2:	asynchronous access protocol, e.g. CSMA, pure-ALOHA packet transmission in point-to-point, point-to-multipoint and broadcast mode for vehicle-to- vehicle, vehicle-to-infrastructure communication.
Layer 3:	single and multihop, internet protocol (IP)
Layer 4-7:	Internet Protocol stack
Functions covered: F1, F2, F13, F14, (F15, F16 to some degree).	

Media access is performed by use of a protocol like CSMA or pure-ALOHA. It is well known that the maximum throughput for such protocols, is much lower than for synchronous systems and that the delay until successful transmission of a packet is non-deterministic. Performance of pure-ALOHA is known to be very small. Analysis has proven CSMA to be a promising protocol, even in a hidden stations environment [Gott 89]. No real-time requirements can be served, however, which results in PROMETHEUS Functions F10, F11, and F12 not being covered by option A. Functions F15 and F16 can be served to some limited degree only.

3.2. Option B, Using a Slotted Radio Channel

Option B of the COMBINE system has improved performance compared to option A. It applies a decentrally controlled slot synchronization mechanism [ZhWa 89], which allows synchronous operation of neighboured stations to support real-time applications through TDMA protocols. The DCF77 radio clock signal, is used as a time reference to derive the slot tact. A decentral slot synchronization algorithm is running in each station, resulting in a time difference of slot starts at different stations, corresponding to the locations, where a station is operating. On that basis the protocols B2-TDMA [Aach 89] and R-BTMA [TaGo 89] are applicable. Common to these protocols is that they are able to perform reservation of periodic slots, whereby channels can be provided.

Characteristics of option B	
Layer 1:	slotted structure
Layer 2:	synchronous multiple-access protocols like B2-TDMA, R-BTMA, etc. packet transmission in point-to-point, point-to-multipoint and broadcast mode for vehicle-to-vehicle and vehicle-to infrastructure communication.
Layer 3:	single and multihop, internet protocol IP
Layer 4-7:	Internet Protocol stack
Functions covered: F1,F2,F10,F11,F12,F13,F14,F15,F16.	

Compared to option A, throughput is improved and delay is significantly reduced. Besides all of the functions covered by option A, in addition functions F10, F11 and F12 needing real-time support can be served. However, the protocols used in option B are inefficient with respect to channel economy and are unable to take advantage of the ISMA protocol, see section 3.3. Both shortcomings are resolved in option C.

3.3. Option C, Using Channel Switched Communication

This option represents the most enhanced system for communication, identification and localization, satisfying all known requirements like high reliability and real-time behavior from PROMETHEUS Functions F1, F2, F10, F11, F12, F13, F14, F15, F16.

Characteristics of Option C	
Layer 1:	framed and slotted channel according to the ISMA structure.
Layer 2:	synchronous protocols CSAP2/DCAP and DMAR for interference free access to channels, assigning channel capacity of the TDMA frame according to the direction of stations' movement. Packet transmission in point-to-point, point-to-multipoint and broadcast mode for vehicle-to-vehicle and vehicle-to-infrastructure communication.
Layer 3:	single and multihop, internet protocol IP
Layer 4-7:	Internet Protocol stack
PROMETHEUS Functions covered: same as option B.	

Option C uses a frame and slot structure permitting to establish TDMA channels each carrying one packet per slot, which is known as the ISMA protocol [HeWa 89.1]. Both packet and channel-switched communication is possible in parallel. To identify free channels in the short-range mobile radio network the CSAP2/DCAP (Decentral Channel Assignment Protocol) [HWRR 89] and DMAR (Decentral Multiple Access with Reservation) protocols [HeWa 89.2] were defined. A free channel is characterized there by two properties: Neither any ongoing communication relationship is disturbed nor any receiver will be unduly interfered in case of a new channel establishment.

The DCAP protocol requires stations to continuously monitor all channels and to continuously transmit the information gained. A bitmap is used for transmitting the monitoring result, where one bit/channel indicates a channel's quality to be good or poor.

The DMAR protocol requires a station to transmit its observations on the quality of all channels, coded in three bit/channel, only when a station is forced through interference to switch from its used to another channel or when a new channel is to be established. The communication partner(s) are able then to calculate all free channels being candidates for use to the interfered station in the channel reuse range and to establish one as substitute for the interfered channel. DMAR is able to decentrally organize the smallest possible spatial channel reuse. No continuous transmission of a bitmap but accidental transmission of 3bit/channel is needed. This feature of DMAR reduces the overhead of CSAP2/DCAP substantially, without reducing the functionality. Both protocols are comparable in their ability to operate in a hidden station environment.

Due to the capability of DCAP and DMAR to rapidly switch from an interfered to a free channel, option C is able to support highly reliable communication channels being well suited for real-time oriented applications. In comparision to option B, throughput, delay and channel economy are improved substantially. Reservation of channel capacity with respect to the direction, in which a station moves is supported, which reduces the probability of channel interference by an order of magnitude.

Option C accomplishes the same Functions as option B but with that performance, reliability and availability needed for all Co-operative Strategies in PROMETHEUS.

4. PROMETHEUS NETWORK (Layer 3) FUNCTIONS

The routing strategies described in this section allow communications with remote vehicles, traffic centers or data-bases. By multi-hop routing, the data packets are forwarded to their destination via other vehicles or roadside beacons acting as relays. Based on a basic concept [Roki 89.3], these routing algorithms are well suited for the complexity of a large mobile network with rapidly changing topology like the integrated PROMETHEUS network, for both vehicle-to-vehicle and vehicle-to-infrastructure communications. The following classes of communications are supported by the routing strategies described in this section:

- vehicle-to-vehicle via other vehicles (PRO-NET)
- vehicle-to-infrastructure via roadside beacons (PRO-ROAD)
- vehicle-to-infrastructure via vehicles and beacons (PRO-NET/PRO-ROAD)
- vehicle-to-vehicle via infrastructure (PRO-NET/PRO-ROAD/PRO-NET)

To satisfy the communication requirements of the various PROMETHEUS Functions [Funct 89], [KrRo 89.1], [Roki 89.2], the following routing strategies have been developed:

- SHORT-RANGE Routing (for short-range communication within the local area)
- DIRECTION-oriented Routing (comms between vehicles and with infrastructure)
- KNOWLEDGE-BASED Routing (especially designed for efficient and robust communications between vehicles (same/opposite direction), vehicles and infrastructure, and between vehicles via roadside infrastructure)

These routing strategies are summarized in the following paragraphs:

4.1. Short-Range Routing (SRR)

Each station (vehicle or beacon) broadcasts periodically information about direct (and indirect) neighbors (possibly transmitted piggy-backed with other data), thus providing the required information for 3-hop routing within the local area [Roki 89.3] for details).

4.2. Direction-Oriented Routing (DOR)

Due to the mobility of vehicles, the network topology changes frequently, especially on two-way roads. Therefore, to support stable routes, direction-oriented routing algorithms have been developed, by which data packets are forwarded to their destination or to the next Fixed Routing Access Node (FRAN) preferably via vehicles moving in the same direction [Roki 89.3].

4.3. Cluster Routing on Knowledge-based Information (KOR)

Due to the rapidly changing network topology, especially with regard to multi-hop communications with opposite traffic on two-way roads, dynamically changing routes according to the actual network topology are essential to provide stable connections between stations. Up to date, known routing algorithms do not support this high flexibility to avoid misrouted packets (caused by inactuality). Therefore, a new concept of "Cluster Routing on Knowledge-based Information" (KOR) has been developed, in which known vehicle characteristics and other important traffic information are taken into account, to forecast the future network topology, and thereby reducing the amount of exchanged routing information significally, thus increasing the user data throughput. See [Roki 90.3] for details.

5. STANDARD PROTOCOLS FOR THE HIGHER LAYERS

The characteristics of an integrated PRO-NET/PRO-ROAD network made it necessary to develop PROMETHEUS specific protocols for the Physical, Data Link and Network Layer, as presented in Sections 2 to 4. However, for communications with remote hosts (data bases, etc.) on computer networks outside the integrated PROMETHEUS network (using network services like File Transfer, Electronic Mail, Virtual Terminal, etc.), standard protocols are required. Therefore it is reasonable, to use a standard protocol stack, for the higher layer protocols.

But even for several PROMETHEUS specific applications (PROMETHEUS Functions) options of standard transport layer protocols can be used. However, for those PROMETHEUS functions with a limited zone of relevance (short-range and local area) and high data/repetition rates, PROMETHEUS specific Transport and higher layer protocols with special performance might be required. Some of them are already being developed.

The ISO/OSI protocol stack is intended to provide protocol standards for open systems interconnection. Currently this protocol suite is not fully specified, and only a few implementations exist. Therefore, it seems to be reasonable to use the INTERNET protocol family, better known as TCP/IP, which is fully specified and has recently developed into de-facto standard for open systems interconnection due to their wide-spread implemenations. The estimated number of TCP/IP hosts is half a million worldwide.

Therefore, a summary of the INTERNET protocol suite is given, a PROMETHEUS specific protocol stack including standard protocols is described, and a possible migration to ISO/OSI and PROMETHEUS protocols is discussed below.

5.1. INTERNET Protocol Suite

Within the last few years, the Internet protocol suite, has developed rapidly into a de facto industry standard for heterogenous packet-switching computer networks. A major goal in the design of this protocol suite, was the specification of a stack of "hardware independent" protocols above a specific network layer, thus allowing the interconnection of a variety of different networks of any type, like local area networks using a broadcast ETHERNET or fiberoptic links, wide area X.25 Public Data Networks (PDN), satellite networks, or packet radio networks, etc. Below is a short description of the most important protocols of the TCP/IP suite.

The Internet system provides packet transport by means of a datagram service for hosts subscribing to the DARPA Internet protocol suite. Due to the widespread implementation under various operating systems (more than 200) and the acceptance of TCP/IP, currently in the Internet there are more than one hundred thousand hosts which are connected to over 1000 networks. In addition, their are thousands of local area networks, also using TCP/IP protocols, which are not connected to any other network.

The basic datagram protocol is the Internet Protocol (IP) [RFC 791]. Error reporting, flow control, first-hop gateway redirection and other control functions are provided by the Internet Control Message Protocol (ICMP) [RFC 792]. Internet transport layer protocols are the Transmission Control Protocol (TCP), which provides reliable end-to-end data stream service, and is equivalent to ISO/OSI Transport Protocol class 4 (TP4), while the much simpler User Datagram Protocol (UDP) is equivalent to the ISO/OSI Transport Protocol class 0 (TP0). All higher layer Internet protocols above use either TCP/IP (e.g. FTP, TELNET, SMTP) or UDP/IP (e.g. NAMESERVER) as the basic packet transport mechanism.

The datagram-oriented characteristic of the Internet Protocol (IP) has important advantages in a mobile environment, where dynamic route changes occur very often. Finally, performance measurements of TCP/IP over broadcast ETHERNETs have shown, that the Internet protocol suite can easily support data transmissions rates in the Megabit per second range.

5.2. PROMETHEUS Protocol Stack

Last year, 23 PROMETHEUS Functions [Funct 89] were specified. For these functions, the communication requirements are currently defined according to a proposed specification structure [KrRo 89.1], [Ernb 89], [Krem 89], [Roki 89.2]. Depending on the function, these communication requirements will vary between a short-range/local and a wide-range/global zone of relevance, high data rates versus low rates, short/long actuality, high/low priority, etc. In addition to the PROMETHEUS Functions, also standard network services like electronic mail (SMTP/X.400), file transfer (FTP/FTAM), virtual terminal (TELNET/VT), for access to remote databases, etc. will be required. To support this wide variety of requirements, the following PROMETHEUS Protocol Stack, including several options is used in the COMBINE system (see Fig. 5.1):

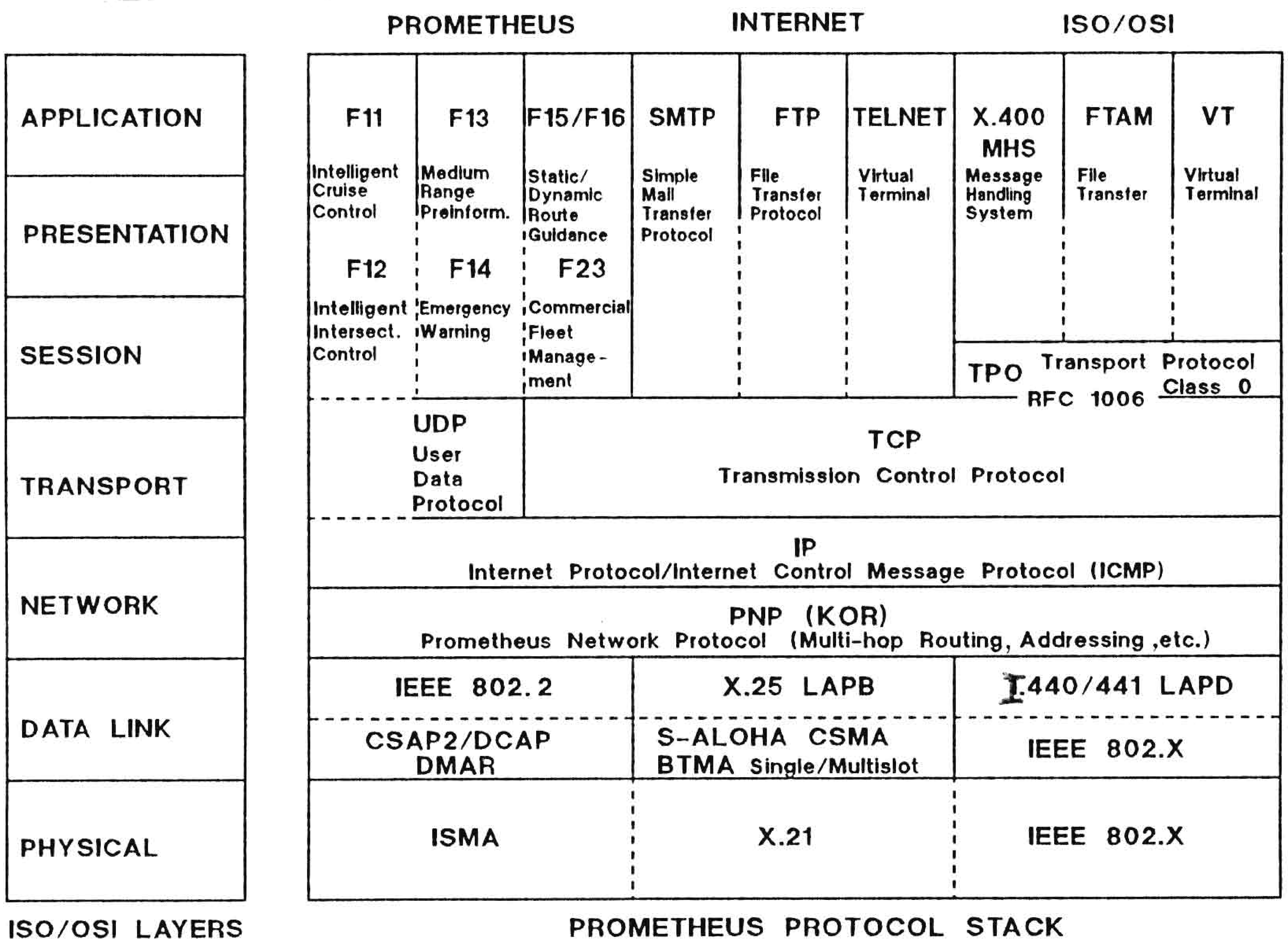

Figure 5.1. PROMETHEUS Protocol stack

The PROMETHEUS specific protocols for the physical, data link and network layer were already presented in Sections 2 to 4.

- Above a PROMETHEUS specific network protocol (PNP), the Internet Protocol (IP) could be used, which already provides several important network functions like addressing, classes of services, fragmentation, "Time To Live" (TTL) field, etc.
- Above IP, for some PROMETHEUS Functions having real-time requirements, which do not need a flow controlled stream "connection", due to the short actuality of the information being transmitted, the User Data Protocol (UDP), which is equivalent to the ISO/OSI Transport Protocol Class 0 (TP0) could be used. In the Internet protocol suite, UDP is used for services like NAMESERVER, TIMESERVER, etc.
- PROMETHEUS Functions requiring a stream connection, with a remote station, or with a database using standard network services (SMTP, FTP, TELNET, etc.), the equivalent of an ISO/OSI Transport Protocol Class 4 (TP4), the reliable end-to-end Transmission Control Protocol (TCP) would be used. Note, that some Internet (Gateway) Protocols (IGP, EGP, etc.) do neither use UDP nor TCP, but sit directly above IP. This might also

be a reasonable option for some PROMETHEUS Functions, as well as a complete bypass of the Internet protocol stack, if the protocol overhead cannot be tolerated.

In addition to the PROMETHEUS Functions and the higher layer Internet protocols, TCP/IP also supports the usage of ISO/OSI applications, which are already defined and implemented (e.g. X.400 Message Handling System, etc.), by providing an interface (see [RFC 1006]) between TCP and the ISO/OSI transport layer (TP0).

The layered architecture of the proposed PROMETHEUS protocol stack of the COMBINE system allows the stepwise introduction of recently developed PROMETHEUS specific protocols (CSAP2/DCAP, DMAR, KOR, etc.) and would also support a possible migration to ISO/OSI protocols, once these protocols are fully available.

6. INTERNETTING AND GATEWAYS TO PUBLIC/PRIVATE NETWORKS

Several PROMETHEUS Functions require communications with remote traffic surveillance and guidance stations, emergency centers (Red Cross, police, fire department), information and reservation systems (weather, time tables, hotel, flight, train), public services (busses, taxi) and databases on other public/private networks. These PROMETHEUS Functions will be supported by the COMBINE system by providing internetting:

- via a PROMETHEUS specific infrastructure network, where available,
- by integration of the GSM mobile celluar network, using traffic channels for data communications with remote hosts, if required,
- by integration of other available communication links (RDS, Paging, Satellite, etc.),
- via other public/private networks (X.25, ISDN, etc.).

If both hosts (source and destination) use the same application protocols, then other public/private networks (GSM, X.25, etc.), can be used as transit networks, thus avoiding unnecessary protocol conversion in PROMETHEUS gateways to these networks. Therefore, the proposed PROMETHEUS protocol stack, including standardized protocols (TCP/IP), would have significant advantages over one, using protocols for some of the higher layers with a similar, but incompatible functionality. Only real-time requirements of some PROMETHEUS Functions and an untolerable protocol overhead would justify this protocol conversion, with the additional disadvantage, that all data packets belonging to the same communication session, would have to travel via such a higher layer gateway.

Specific gateway algorithms (PDN Cluster Addressing, Hierarchical VAN-Gateway algorithms, etc.) have already been specified for the interconnection of the proposed PROMETHEUS protocol stack to support internetting between PROMETHEUS hosts via the system of X.25 Public Data Networks (PDN), as well as worldwide access to remote data bases on the PDN, see [Roki 88.1], [Roki 89.5].

7. EARLY NATIONAL/EUROPE-WIDE FIELD TRIALS

Of significant importance for the performance evaluation of the specified PROMETHEUS Functions and communication protocols (Media Access Control, Multi-hop Routing, etc.) are careful analysis and computer simulations based on realistic road traffic scenarios and mobility models (see [Roki 89.4]and [Roki 90.2]). However the parameters (e.g. communication channel, driver behaviour, etc.) used in these simulations might not describe the real world with the required accuracy. Therefore, early field trials are essential for the evaluation and further refinement of the developed protocols and functions, to investigate:

- the characteristics of the communication channel by measurements,
- performance of the specified channel access protocols (CSAP2/DCAP, DMAR, B2)
- performance of developed routing strategies (KOR)
- performance of defined PROMETHEUS Functions
- driver behaviour by measurements,
- evaluation of user acceptance, etc.,

7.1. Early Field Trials

Currently, the communication protocols of the COMBINE system are tested in an experimental packet radio network at the Fern University of Hagen. The following four phases have been defined for these field trials:

Phase 0: Install an experimental packet radio network based on standard protocols (TCP/IP, ISO/OSI, AX.25, etc.), demonstrate functionality and perform measurements. (First demo already done at the PROMETHEUS/DRIVE(VIC) meeting, Fern University of Hagen,March 5/6, 1990).

Phase 1: Replace the current asynchronous media access control (CSMA) with recently developed synchronous access protocols (CSAP2/DCAP, DMAR, etc.), implement the developed multi-hop routing strategies (KOR), proof functionality and perform measurements.

Phase 2: Replace/extend the low speed radio equipment with high speed microwave transceivers, measure performance of the developed communication protocols, and demonstrate support for PROMETHEUS Functions and DRIVE applications, including the integration of other existing mobile networks (GSM, RDS, Paging, Satellite, etc.) and access to public/private networks (X.25, ISDN, etc.).

Phase 3: Refine the developed communication protocols based on measurements of field trials and simulation results, and specify protocol standards for PROMETHEUS/DRIVE.

Field trials would allow performance evaluation of all types of communcation equipment using various frequency bands ((144 MHz), 430 MHz, 1.2 GHz (Amateur Packet Radio), 5.8 GHz (BOSCH), 60 GHz (AEG), etc.).

7.2. Nationwide/Europeanwide Field Trials (STAR)

To provide a testbed with a large number of participating sites for performance evaluation of recently developed communication protocols and PROMETHEUS Functions, and their acceptance by users, the following System Trial using Amateur Radio (STAR) project is proposed:

Currently, the europeanwide Amateur Packet Radio Network consists of several ten thousands of users, using the Amateur X.25 protocol (AX.25) as the basic protocol for communication between fixed and mobile stations (on 144 MHz (2m), 430 MHz (70 cm) and 1.2 GHz (23cm)) and via digipeaters, which are interconnected by microwave links. Some Amateur Packet Radio people do already use the TCP/IP protocol suite on top of AX.25.

Interested members of this europeanwide Amateur Packet Radio network could be invited to participate in a nationwide/europeanwide field trial for the performance evaluation of developed communication protocols and PROMETHEUS Functions.

Instead of AX.25 only, the whole PROMETHEUS protocol stack, as presented in Section 5, would be used, according to Phase 0 and Phase 1 described above.

A first catalog of possible functions to be evaluated could include:

- Monitoring Environment Road (F2) (Valid traffic signs/regulations for specific road sections)
- Monitoring Driver (F3) (Reaction Selftest)
- Intelligent Cruise Control (F11) (Distance keeping between vehicles (restrictions apply))
- Medium Range Preinformation (F13) (Traffic congestion, wheather conditions (ice, fog,))
- Emergency Warning (F14) (Emergency Call and Emergency Warning to other vehicles)
- Static/Dynamic Route Guidance (F15/F16) (Route suggestion with heading info on turnpoints)
- Theft Signalling/Tracking (Detection/automatic tracking of stolen vehicle/radio)
- Mailbox Service (exchange of traffic/wheather info between road users via mailboxes)
- Standard Network Services (Email, File Transfer, Virtual Terminal, etc.)

The trial offers the opportunity to investigate in addition, what traffic related information can be provided by co-operative drivers to the system. This service is currently not considered a PROMETHEUS Function.

Disadvantageous is that amateurs might not have available some of the required computer equipment. An initial interest group would probably need some financial support for computer equipment (Pocket-PC, etc.). The low speed transmission rates of the current Amateur Packet Radio equipment might be advantageous with regard to worst case scenarios for performance evaluation of the developed communication protocols, since the limits will be reached soon even with a small number of participating test sites (vehicles), while a (non-available) large number of test vehicles would probably be required when using high speed transceivers.

Main important advantages of the proposed nationwide/europeanwide STAR project are:

- Large number of potentially participating stations (Germany ~ 10.000),
- Nationwide/Europeanwide coverage is possible,
- Radio equipment is already available,
- Variety of measurements and performance evaluation tests can be performed,
- Inclusion of satellite communication is possible,
- Performance evaluation of defined PROMETHEUS Functions is possible,
- User acceptance of proposed PROMETHEUS Functions can be evaluated,
- Amateur packet radio people have technical experience to support such field trials, they are reliable and motivated (new technology),
- Sources of messages can be identified by callsigns,
- People at fixed stations (simulating infrastructure) could be included in the trial,
- Traffic surveillance and guidance stations, police, etc. could support the project,
- Field trial does not require allocation of a new, europeanwide available frequency band,

- Realization of a europeanwide field trial within a short time would be possible (1990/91).

The principal feasibility of the project has already been discussed with DARC officials. For a detailed description of the proposed nationwide/europeanwide STAR project see [Roki 90.1].

REFERENCES

[Aach89] F.Reichert et. al: B2-TDMA. Presentation at Int. PROCOM Meeting, DLR. Oberpfaffenhofen, Sept. 89.

[Ernb89] P. Ernberg, B. Pehrsson, K. Laraqui, A. Nazari, C. Odmalm, M. Svärdh: A PROMETHEUS - PROCOM Framework, Proc. 2nd PROMETHEUS Workshop, Stockholm, Oct. 1989, pp 433-442.

[FoGr89] P. Form, U. Grotheer: A transponder based communication system. Proc. 2nd PROMETHEUS WORKSHOP, Stockholm, Oct. 1989, pp. 443-452.

[Funct 89] "Functions" or how to achieve PROMETHEUS "Objectives", PROMETHEUS Office, Stuttgart, July 1989, 81 pages.

[Gott89] C. Gotthard: Durchsatz in CSMA multi-hop Netzen. Informatik Fachberichte 205, Springer Verlag Berlin 1989, S. 309-323.

[HABHW89] P. Henricsson, et. al: COMPOSE, a transceiver/transponder system for communication and relative positioning. Proc. 2nd PROMETHEUS WORKSHOP, Stockholm, Oct. 1989, pp. 327-337.

[HeWa89.1] T. Hellmich, B. Walke: Highly reliable radio channels for PROMETHEUS applications, Proc. 1st PROMETHEUS WORKSHOP, Wolfsburg, May 1989, pp. 293-299.

[HeWa89.2] T. Hellmich, B. Walke: DMAR - A Decentral Multiple Access protocol with Reservation, 2. Informationskonferenz "Aktuelle Forschung", FernUniversity Hagen, Dec. 1989.

[HWRR89] T.Hellmich, B.Walke, F.Reichert, J.Kaltwasser: CSAP-2 - A mobile network media access protocol, Proc. 2nd PROMETHEUS WORKSHOP, Stockholm, Oct. 1989, pp. 490-502.

[Krem 89] W.Kremer, C.-H. Rokitansky, F. Reichert, J. Kassubek: A Specification Structure for PROMETHEUS Services and Applications,Detailed Report, 2. Edition, 64 pages, RWTH Aachen, FernUniversity of Hagen, June 1989.

[KrRo 89.1] W.Kremer, C.-H. Rokitansky, F. Reichert, J. Kassubek: A Specification Structure for PROMETHEUS Services and Applications, Short Report, Proceedings 1st PROMETHEUS WORKSHOP, pp. 312-324, Wolfsburg, May 1989.

[RFC791] Postel, J., ed.: "Internet Protocol - DARPA Internet Program Protocol Specification", DARPA Network Working Group Request For Comments, RFC-791, USC/Information Sciences Institute, Sept. 1981.

[RFC792] Postel, J., ed.: "Internet Control Message Protocol - DARPA Internet Program Protocol Specification", RFC-792, USC/Information Sciences Institute, Sept. 1981.

[RFC793] Postel, J., ed.: "Transmission Control Protocol", RFC 793, USC/Information Sciences Institute, Sept. 1981.

[RFC1006] M.T. Rose, D.E. Cass: ISO Transport Services on top of the TCP, Version 3", RFC 1006, Northrop Research and Technology Center, May 1987.

[Roki 88.1] C.-H.Rokitansky: Internet Cluster Addressing Scheme and its Application to Public Data Networks Proceedings ICCC'88, 9th Int. Conf. on Computer Communications, pp. 482-491, Tel Aviv, Israel, Oct. 30-Nov. 3, 1988.

[Roki 89.2] C.-H.Rokitansky: Specification Structure and Communication Characteristics For PROMETHEUS Functions and Basic Services, Proc. of 2nd PROMETHEUS WORKSHOP, pp. 615-620, Stockholm, October 1989.

[Roki 89.3] C.-H.Rokitansky: Basic Routing Concept - Short Range and Direction-Oriented Multi-hop Routing Algorithms for PRO-NET/PRO-ROAD Communication, Proc. 1st PROMETHEUS WORKSHOP, pp. 325-340, Wolfsburg, May 1989.

[Roki 89.4] C.-H Rokitansky: SIMCO: Simulation of PRO-NET/PRO-ROAD communications to support PROMETHEUS functions based on a realistic dynamic network, Proc. of 2nd PROMETHEUS WORKSHOP, pp. 597-614, Stockholm, October 1989.

[Roki 89.5] C.-H. Rokitansky: Hierarchical VAN-Gateway algorithms and PDN-cluster addressing scheme for worldwide interoperation between Local TCP/IP Networks via X.25 Networks, Proc. ITG/GI Conf. on Communication in Distrib. Systems, Stuttg., Feb. 1989, pp. 758-774.

[Roki 90.1] C.-H Rokitansky: Proposal of a europewide field trial... This conference.

[Roki 90.2] C.-H. Rokitansky: Integrated Simulator for Performance Evaluation of Communication Protocols and PROMETHEUS Functions, to appear in Proc. of 3rd PROMETHEUS Workshop, Turin, Apr. 1990.

[Roki 90.3] C.-H. Rokitansky: Cluster Routing On Knowledge-Based Information For an Integrated PRO-NET/PRO-ROAD Network, to appear in Proc. of 3rd PROMETHEUS Workshop, Turin, Apr. 1990.

[TaGo89] S. Tabbane, P. Godlewski: Study and Performance Analysis of the R-BTMA medium access protocol. Proc. of 2nd PROMETHEUS WORKSHOP, Stockholm, October 1989, pp. 648-656.

[ZhWa89] W. Zhu, B. Walke: Decentralized frame synchronisation method for stations in PROMETHEUS environment, Proc. 2nd PROMETHEUS WORKSHOP, pp. 657-662, Stockholm, Oct. 1989.