

"Telecommunication network with improved access protocol"

The invention is related to a telecommunication network comprising a primary station and a plurality of secondary stations, the secondary stations being linked to the primary station via a transmission medium being at least partly in common for a number of secondary stations.

5 The invention is also related to stations for use in such network and to a communication method for such networks.

A telecommunication network according to the preamble is known from the conference paper "Network Evolution for End User Access to Interactive Digital Services" by C.-J.L. van Driel and W.A.M. Snijders, Proceedings of "The Last Mile of the
10 Information Superhighway", IBC conference, Sydney, August 1994.

Such telecommunication networks are used for the communication between several secondary stations to a primary station, via a transmission channel being, at least partially, common to some of the secondary stations. Such transmission channel can comprise an optical fibre, a coaxial cable, or a radio link. Application of such transmission
15 systems can be passive optical networks, cable TV systems, local area networks, systems for satellite communication and mobile radio systems.

In transmission systems utilising a common channel for some secondary stations it must be ensured that no interference is caused by secondary stations simultaneously transmitting information to the primary station. To ensure an adequate service
20 for the secondary stations, it is required that the efficiency of the data transport over the network is high, in particular under heavy load conditions.

There exist a lot of different access protocols, like Aloha and slotted Aloha for such type of networks. However these protocols suffer from a very low efficiency under heavy load conditions.

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It is an object of the present invention to provide a telecommunication network according to the preamble having a high efficiency under high load conditions.

Therefor the telecommunication network is characterised in that the

secondary stations comprise request transmitting means for transmitting a transmission request signal to the primary station, the primary station comprises allocation transmitting means for transmitting an allocation signal to the secondary stations in response to transmission request signals received, in that the secondary stations comprise payload transmitting means for transmitting in response to the allocation signal payload data in turn to the primary station, and in that the request transmitting means are arranged to transmit a transmission request signal to the primary station directly after transmission of payload data by the secondary stations.

By having the secondary stations which have payload data to be transmitted to the primary station to transmit a transmission request signal, the primary station knows the secondary stations which have payload data for the primary station. Thereafter the primary signals to the secondary stations an allocation signal indicating a timeslot they may use. Subsequently the secondary stations transmit their payload data to the primary station in the timeslot assigned to them. After the transmission of payload data by the secondary station has been completed, the secondary station transmit their next request signal for the next transmission cycle. It is also conceivable that the next transmission request signals are transmitter after a predetermined amount of payload data is transmitted by the secondary stations. This can lead to a more efficient transmission, because it is not required that all the secondary stations have to wait for the allocation signal before transmitting their payload data.

Under high load conditions the transmission path from secondary stations to the primary station is mostly filled with payload data from the secondary stations, leading to a high efficiency.

An additional advantage is that the delay a substation encounters when transmitting data to the primary station is bounded to some maximum value. Because the substations transmitting a transmission request signal are granted a timeslot shortly after their transmission, it is ensured that the delay a substation encounters is bounded to some maximum value. The actual transmission available for each secondary station depends on the transmission load of the network.

It is observed that the book "Computer Networks" by A.S. Tanenbaum, published by Prentice-Hall, 1989, ISBN 0-13-166836-6 pp 130-131 discloses a protocol having an high efficiency under heavy load conditions, and having a upperbound to the delay. However in this protocol no primary station is present, that receives transmission request signals from the secondary stations and issues allocation signals to them.

A further embodiment of the invention is characterised in that the request transmitting means of a secondary station are arranged for transmitting the transmission request signal during a timeslot associated to said secondary station.

5 An easy way of distinguishing the transmission request signals from different secondary stations is associating a timeslot to said secondary station wherein said secondary station has to transmit its transmission request signal.

A further embodiment of the invention is characterised in that the allocation transmitting means are arranged for transmitting the transmission request signals as received by the primary station, as allocation signal.

10 Retransmission of the received transmit request signals as allocation signal is a simple way of providing an allocation signal. The secondary station receiving said allocation signal then know all the other secondary stations that have payload data to be transmitted to the primary station. Having this information they can determine a time slot number they can transmit in. This can e.g. be done by allowing transmission by the
15 secondary stations in an order determined by a rank number associated to the secondary stations.

A further embodiment of the invention is characterised in that the payload transmitting means are arranged for transmitting in a predetermined number of symbol intervals a integer plurality of short information cells, or one single synchronous transfer
20 mode cell.

Arranging the payload transmission means for transmitting a number of short information cells or one single ATM cell results in a network allowing the transmission of several types of signals during one predetermined time interval. This is advantageous for higher level protocols that only have to cope with one predetermined time interval of
25 transmission by each secondary stations.

A first choice for the size of the short information cells is characterised in that the short information cells have a size of sixteen bytes, and in that the predetermined number of short information cells is equal to four. Using four short information cell of 16 bytes results in 64 bytes in total, which can also carry one ATM cell (53 bytes) plus some
30 additional overhead information.

A second choice for the size of the short information cells is characterised in that the short information cells have a size of nine bytes, and in that the predetermined number of short information cells is equal to six. Using six short information cell of 9 bytes results in 54 bytes in total, which can also carry one ATM cell (53 bytes) plus one additional

overhead byte.

The invention will now be explained referring to the drawings. Herein
5 shows

Fig. 1, a two-way cable network in which the invention can be applied;

Fig. 2, a primary station for use in a network according to Fig. 1;

Fig. 3, a secondary station for use in a network according to Fig. 1;

Fig. 4, a conceptual drawing of the access protocol according to the
10 invention;

Fig. 5, upstream and downstream signals in the network according to Fig.
1 using the protocol according to the invention;

Fig. 6, upstream and downstream signals in the network according to Fig.
1 using the protocol according to the invention, but having a transmission request signals
15 interleaved in the payload data associated with previous request signals.

In the cable network according to Fig. 1 a head end 2 is connected via a
trunk network 4 to a primary station, being here a local node 6, and to several other primary
20 stations. An input/output of the primary station 6 is connected with an input of a forward
path amplifier 8 and to an output of a return path amplifier 10. The output of the forward
path amplifier 8 and the input of the return path amplifier 10 are connected to a plurality of
feeder cable sections 13 14 and 15. The feeder cable section 14 is connected to an input of a
forward path amplifier 12 and to an output of a return path amplifier 16. The output of the
25 forward amplifier 12 and the input of the return path amplifier 16 is connected to drop cable
sections 18, 20, 22, 24, 26 and 28, which drop cable sections are connected to secondary
stations 30, 32, 34, 36, 38 and 40.

The cable network according to Fig. 1 basically consists of three sections:
the trunk network, the feeder network and the drop network. The trunk network 4 is
30 arranged for connecting the head end 2 to the local nodes. Optical fibre is often used in the
trunk network 4, but also coaxial cable can be used in the trunk network 4. If the cable
network has to serve a large area, the use of optical fibres in the trunk network can result in
substantially lower costs.

Each local node is arranged for serving 100-1500 secondary stations. The

forward path amplifier 8 and the return path amplifier 10 are arranged to have non overlapping pass bands in order to prevent instability. Currently the pass band of the return path amplifiers is from 5 MHz to 42 MHz, and the pass band of the forward path amplifiers is from 55 to 750 MHz. The output signal of the amplifier 8 is splitted into signals for the feeder cable sections 13, 14 and 15. The upstream signals from the feeder cable sections 13, 14 and 15 are combined to an input signal for the return path amplifier 10. The signal from feeder cable section 14 is amplified in the forward path amplifier 12, and distributed to the secondary stations 30 . . . 40 via the drop cable sections 18 . . . 28. The signals from the secondary stations is transmitted via the drop cable sections 18 . . . 28 and combined at the input of the return path amplifier 16.

To prevent mutual interference between upstream signals several techniques are used. In general a plurality of upstream carriers in the return frequency range from 5-42 MHz are used, each of them having N secondary stations allocated to them. To prevent interference between the upstream signals sent by the N secondary stations an access protocol according to the invention is applied.

It is conceivable that the primary station is not the local node 6, but that all the functions of the primary station are concentrated in the head end 2. The trunk network 4 then has to be arranged for passing the upstream signals arriving at the local nodes to the head end 2.

In the local node 6 according to Fig. 2, a wide band distribution signal is applied to a first port of a signal combiner/splitter 58 via a band pass filter 57. An ATM gateway 42, A SONET/SDH gateway 44, a Frame Relay gateway 46, and an X.25 gateway 48 are connected to a protocol converter/modem 52. The protocol converter/modem 52 is connected to a second port of the combiner/splitter 58. A telephone exchange 54 is coupled to the PSTN network and to a protocol converter/modem 56. The protocol converter/modem 56 is coupled to a third port of the combiner/splitter 58. An input/output of the combiner/splitter 58 constitutes the input/output of the local node 6.

The local node 6 is arranged to provide different types of services to the secondary stations. A distribution signal as received from the head end via the trunk network 4 is applied directly to the combiner/splitter 58. The distribution signal mainly comprises a plurality of TV signals modulated on respective carriers in the 55-750 MHz band.

The gateways 42, 44, 46 and 48 are arranged to interface the cable network to a public ATM network, A public SONET/SDH network, a frame relay network and an X.25 network respectively. Data signals to be transmitted via the gateways 42 . . . 48

is received from the feeder cable sections, demodulated and converted into the desired protocol by the protocol converter/modem 52. Data signals received from the gateways 42 . . . 48 is converted into the format used on the cable network and modulated on a carrier by the protocol converter/modem 52.

5 The transmission request signals received from the secondary stations are detected by the protocol converter/modem 52 and passed to the control unit 50. After having processed the transmission request signals, the control unit 50 passes the allocation signal to the protocol converter/modem 52 which multiplexes the allocation with the payload data received from the gateways 42,44,46 and 48. The multiplexed signal is modulated on a
10 carrier by the protocol converter/modem 52 for transmission to the secondary stations. Here the allocation transmission means are constituted by the combination of the protocol converter /modem 52 and the control unit 50.

A telephone exchange 54 is present for interconnecting telephone calls between secondary stations in the cable network. A protocol converter/modem 56 is arranged
15 for interfacing the cable network to the telephone exchange. The telephone exchange 54 is connected to the public telephone network for enabling calls to be made outside the cable network by the secondary stations.

In the secondary station 30 . . . 40 according to Fig. 3 a drop cable section is connected to an input of a band pass filter 60, to a protocol converter/modem 64
20 and to a protocol converter/modem 66. The protocol converter modem 64 is connected to a TV interface 72, an Ethernet interface 68 and an (narrow band) ISDN interface 70. The output of the band pass filter 60 and the output of the TV interface are connected to a signal combiner 74. The output of the protocol converter/modem 66 is coupled to a telephone interface 76.

25 In the secondary station according to Fig. 3, the distribution signal to be applied to a TV receiver is extracted from the input signal received from the drop cable section. Said distribution signal is coupled via the bandpass filter 60 to the combiner 74, where it is combined with control signals from the TV interface 72 for a set top box. Such control signals can e.g. comprise a key for decrypting an encrypted video signal, in order to
30 enable reception of said video signal by authorised users only.

The output of the Ethernet interface 68 provides a connection for one or more PC's. The output of the ISDN interface can be connected to a ISDN telephone or to a videophone terminal. Finally the telephone interface 76 provides access to the network for an analog telephone set. It is observed that not all possibilities as discussed have to be realised

in the primary and/or secondary stations.

The transmission request transmission means are constituted by the combination of protocol converter/modem 64 and control unit 62, and the payload transmission means are constituted by the combination of protocol converter/modem 64, control unit 62 and the active interface from the interfaces 86 and 70. The control unit 62 detects whether there is data to be transmitted by one of the interfaces. If so the control unit 62 submits a transmission request signal to the protocol converter/modem 64 which passes said signal to its modulator which switches on a carrier at the correct instant for transmission to the primary station. The protocol converter/modem 64 recognises an allocation signal received by the secondary station, and passes it to the control unit 62. After some processing, the control unit 62 initiates the transmission of payload data by the protocol converter/modem 64 to the primary station.

In Fig. 4 the access protocol to be used by the secondary station to access the common channel is presented. According to the inventive concept the secondary stations are provided with request transmitting request signals indicating that said secondary station has data to be transmitted. The request transmitting means are incorporated in the protocol converter/modem 64 in Fig. 3. In Fig. 3 it can be seen that there is a request cell R in which the secondary stations can transmit their transmission request signal. The request interval is subdivided into M sub-slots, where $M \leq N$. To each of the N secondary stations one unique sub-slot is allocated, so that every secondary station is able to signal that it has data to be transmitted.

For the analysis to follow all durations are expressed in symbol periods, a symbol period being the time required for transmitting one basic symbol. To signal that a secondary station has data to transmit, it switches on a carrier in its subslot. If it is assumed that the switching time is g_s symbols, and the time to detect the carrier in the primary station is equal to d_{ss} symbols, the duration of the sub-slot S_{ss} has to be at least equal to:

$$S_{ss} = d_{ss} + 2g_s \quad (1)$$

If the duration of a request cell is S_{mc} symbols, the number of sub-slots M in a request cell is equal to:

$$M = \left\lfloor \frac{S_{mc}}{S_{ss}} \right\rfloor \quad (2)$$

It is further assumed that all payload data is transmitted using an info-cell

which comprises a number of V mini cells. It is assumed that the request cell has the same duration S_{mc} as a minicell.

After the request cell has been filled with request signals from the various secondary stations, all the secondary stations that have transmitted a transmit request signal are enabled in turn to transmit an information cell to the primary station. This enabling takes place W_0 mini cells after the request cell has ended. If a secondary station i is the only station having transmit a transmit request signal, the info-cell of said station can be transmitted W_0 symbol periods after the request cell has ended. If all secondary stations having a rank number lower than i have submitted a transmit request signal secondary station i can transmit its info-cell $W_0 + iV$ symbol periods after the request cell has ended.

If the i^{th} secondary station wants to submit a transmit request, it might just have missed its sub-slot in the request cell. In that case there are maximum $S_{mc} - i$ sub-slots in the request cell left. If the number of mini-cells between two request cells is limited to W_1 , one obtains for the upper bound to the delay D_i of the payload data from secondary station i :

$$D_i = S_{mc} - i S_{ss} + W_1 S_{mc} + W_0 S_{mc} + i V S_{mc} \quad (3)$$

In (3) it is assumed that at least i info-cells are available between two request cells. This condition can be expressed as $i+1 \leq (W_1 - W_0)/V$. (3) can also be written as:

$$D_i = S_{mc} \left[2 + W_1 + W_0 + i \cdot \left(V - \frac{S_{ss}}{S_{mc}} \right) \right] \quad (4)$$

If $i+1 > (W_1 - W_0)/V$ an extra request cell is present because the last info-cells indicated by the first request cell are transmitted in the period W_0 after the second request cell. This results in an upper bound on the delay being equal to:

$$D_i = S_{mc} \left[3 + W_1 + W_0 + i \cdot \left(V - \frac{S_{ss}}{S_{mc}} \right) \right] \quad (5)$$

By neglecting S_{ss}/S_{mc} the upper bounds according to (4) and (5) can be simplified:

$$D_i = S_{mc} (2 + W_1 + W_0 + iV); i+1 \leq \frac{(W_1 - W_0)}{V} \quad (6)$$

$$D_i = S_{mc} (3 + W_1 + W_0 + iV) ; i+1 > \frac{(W_1 - W_0)}{V} \quad (7)$$

If the number N of secondary stations is larger the number of transmission requests that can be transmitted in one mini-cell, the number of request cells has to be increased to a number $\lceil N/M \rceil$. This means that to the value of W_1 a value $\lceil N/M \rceil - 1$ has to be added. For the upper bound D_{max} for the delay can now be derived by substituting the new value for W_1 in (7):

$$D_{max} = S_{mc} \left(2 + V + 2NV + \lceil \frac{N}{M} \rceil \right) \quad (8)$$

It is observed that (8) is also valid for $N \leq M$ because in that case $\lceil N/M \rceil$ is equal to 1 and W_1 assumes its original value.

The efficiency E of the system can be calculated very easily. Under low load conditions one request cell per info-cell is required. This results in:

$$E_{low} = \frac{VS_{mc}}{S_{mc} + VS_{mc}} = \frac{V}{1+V} \quad (9)$$

10 Under high load conditions all N secondary stations will be submitting transmit request signal continuously, resulting into N info-cells between two subsequent request cells. For the efficiency E_{high} then is found:

$$E_{high} = \frac{NVS_{mc}}{S_{mc} + NVS_{mc}} = \frac{NV}{1+NV} \quad (10)$$

Consequently the efficiency E is bounded between:

$$\frac{V}{1+V} \leq E \leq \frac{NV}{1+NV} \quad (11)$$

Using (8) and (11) the delay and the efficiency of the return channel can be calculated for different values of S_{mc} , V , W_0 and N . The results of said calculation are presented in the table given below. It is further observed that a modulation scheme is used enabling the transmission of two bits per symbol.

	load	N	S_{mc}	S_{ss}	V	W_0	W_1	E	R_{ch}	$R_{station}$	D_{max}
5	high	8	64	8	4	8	32	97%	2Mb/s	248kb/s	3.3ms
	low	8	64	8	4	8	32	80%	2Mb/s	1.6Mb/s	
	high	288	64	8	4	8	1979	97%	2Mb/s	8kb/s	109ms
	low	288	64	8	4	8	1979	6%	2Mb/s	120kb/s	
	high	18	36	2	6	12	108	99%	2Mb/s	113kb/s	6.2ms
	low	18	36	2	6	12	108	86%	2Mb/s	1.7Mb/s	
10	high	288	36	2	6	12	2957	99%	2Mb/s	8kb/s	107ms
	low	288	36	2	6	12	2957	18%	2Mb/s	372kb/s	

In the case where V is equal to 4 and S_{mc} is equal to 64, a mini-cell can carry 16 bytes and an information cell or request cell can carry 64 bytes. This is sufficient for carrying one ATM cell (53 bytes) plus some additional overhead. If only one request cell is used and if S_{ss} is equal to 8, the maximum value of N is 8. By using a plurality of mini-cells which can comprise an ATM packet is possible to have a system that can use mini-cells for carrying voice related data having a low transmission delay, and which can also transmit ATM cells having a larger transmission delay.

In the case where V is equal to 6 and S_{mc} is equal to 36, a mini-cell can carry 18 bytes and an information cell or request cell can carry 54 bytes. This is sufficient for carrying one ATM cell (53 bytes) plus one additional overhead byte. If only one request cell is used and if S_{ss} is equal to 2, the maximum value of N is 18.

In the case N is equal to 288 the number of request cells has to be increased in the first case to 36. In the second case the number of request cells has to be increased to 18. From the table it can clearly be seen that the efficiency under high load is excellent for all cases. It can also be seen that the delay has a maximum value of approximately 100ms, which is acceptable for most applications.

Fig. 5 shows a first possibility of the relation between the downstream data D and the upstream data U. From Fig. 5 it can be seen that the secondary stations start with transmitting their info-cells in turn after the allocation signal S has been received from

the head-end. Hereby is a cell indicated with CELL i , in which i is an integer number, a cell originated by a secondary station with rank number i . After all secondary stations have transmitted their info-cells, the secondary stations having payload data available transmit a transmission request signal in a corresponding time slot in the request cell. Subsequently the
5 secondary stations wait until the request signals have been processed by the primary station and the allocation signal has been received. Between the subsequent allocation signals, the primary station transmits payload data destined for the secondary stations.

If the processing time of the transmission request signals can be long, this can lead to some efficiency loss of the upstream link, due to the waiting for the allocation
10 signal.

Fig. 6 shows a solution to said problem. Now the secondary stations are arranged to transmit the transmit request signals in a request cell following the last but one info-cell to be transmitted by the secondary stations. The final info-cell is transmitted direct after the request-cell. In this way the waiting time for the allocation signal does not result in
15 a decreased efficiency of the upstream transport mechanism.

CLAIMS

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1. Telecommunication network comprising a primary station and a plurality of secondary stations, the secondary stations being linked to the primary station via a transmission medium being at least partly in common for a number of secondary stations, characterised in that the secondary stations comprise request transmitting means for transmitting a transmission request signal to the primary station, the primary station comprises allocation transmitting means for transmitting an allocation signal to the secondary stations in response to transmission request signals received, in that the secondary stations comprise payload transmitting means for transmitting in response to the allocation signal payload data in turn to the primary station, and in that the request transmitting means are arranged to transmit a transmission request signal to the primary station directly after transmission of payload data by the secondary stations.
2. Telecommunication network according to claim 1, characterised in that the request transmitting means of a secondary station are arranged for transmitting the transmission request signal during a timeslot associated to said secondary station.
3. Telecommunication network according to claim 1 or 2, characterised in that the allocation transmitting means are arranged for transmitting the transmission request signals as received by the primary station, as allocation signal.
4. Telecommunication network according to one of the claims 1 to 3, characterised in that the payload transmitting means are arranged for transmitting in a predetermined number of symbol intervals a integer plurality of short information cells, or one single synchronous transfer mode cell.
5. Telecommunication network according to claim 4 characterised in that the short information cells have a size of sixteen bytes, and in that the predetermined number of short information cells is equal to four.
6. Telecommunication network according to claim 5, characterised in that the short information cells have a four byte header, and in that a the synchronous transfer mode cell is provided with an additional four byte header.
7. Telecommunication network according to claim 4 characterised in that the short information cells have a size of nine bytes, and in that the predetermined number of



short information cells is equal to six.

8. Telecommunication network according to claim 7, characterised in that the short information cells have a one byte header, and in that a the synchronous transfer mode cell is provided with an additional one byte header.

5 9. Secondary station, for use in a telecommunication network, in which a plurality of secondary stations are linked to a primary station via a transmission medium being at least partly in common for a number of secondary stations, characterised in that the secondary station comprise request transmitting means for transmitting a transmission request signal, in that the secondary station comprises payload transmitting means for transmitting in
10 response to an allocation signal payload data to the primary station, and in that the request transmitting means are arranged to transmit a transmission request signal to the primary station directly after transmission of payload data by the secondary stations.

10. Secondary station according to claim 9, characterised in that the request transmitting means are arranged for transmitting the transmission request signal during a
15 timeslot associated to said secondary station.

11. Secondary station according to claim 9 or 10, characterised in that the payload transmitting means are arranged for transmitting in a predetermined number of symbol intervals a integer plurality of short information cells, or a single synchronous transfer mode cell.

20 12. Primary station, for use in a telecommunication network in which a plurality of secondary stations are linked to the primary station via a transmission medium being at least partly in common for a number of secondary stations, characterised in that the primary station comprises request reception means for receiving a transmission request signal transmitted by secondary stations, the primary station comprises allocation transmitting
25 means for transmitting an allocation signal to the secondary stations in response to transmission request signals received, in that primary station comprises payload reception means for receiving data transmitted by the secondary stations, and in that the request reception means are arranged for receiving request signals after reception of payload data.

13. Primary station according to claim 12 characterised in that the allocation
30 transmitting means are arranged for transmitting the transmission request signals as received by the primary station, as allocation signal.

14. Communication method for use in a network comprising a primary station and a plurality of secondary stations, the secondary stations being linked to the primary station via a transmission medium being at least partly in common for a number of secondary





stations, characterised in that the method comprises transmission during a predetermined period a transmission request signal by at least one secondary station to the primary station, transmitting an allocation signal to the secondary stations in response to the transmission request signal received, and transmission in response to the allocation signal payload data by
5 the secondary stations turn to the primary station, and in that the method comprises transmit a transmission request signal to the primary station directly after transmission of payload data by the secondary stations.

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