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(71) Applicant(s)
GPT Limited

(Incorporated in the United Kingdom)

PO Box 53, New Century Park, Telephone Road, COVENTRY, CV3 1HJ, United Kingdom

(72) Inventor(s)
Geoffrey Chopping
Alexander Schroder Philip

(74) Agent and/or Address for Service
Jonathan Rodwell
GEC Patent Department, Waterhouse Lane, CHELMSFORD, Essex, CM1 2QX, United Kingdom

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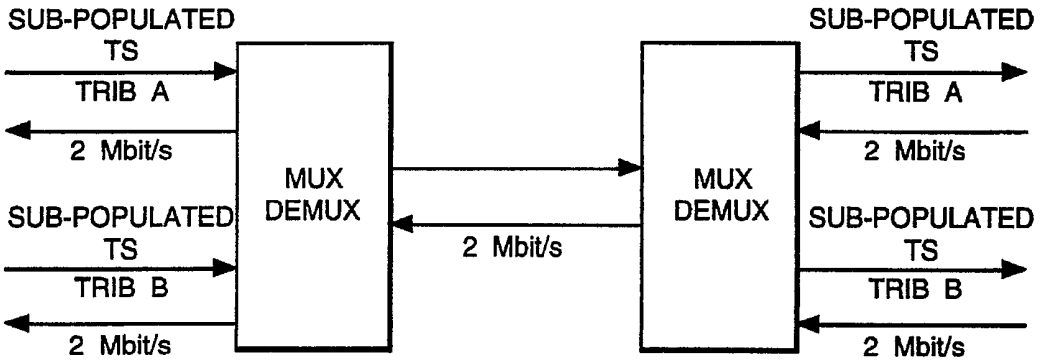
(56) Documents Cited
GB 2204764 A **US 4807221 A**

(58) Field of Search
UK CL (Edition L) **H4M MN MTCA1 MTCA2 MTCA3 MTCX1 MTCX2 MTCX3 MTP1 MTP2 MTP3**
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ONLINE DATABASES : WPI; INSPEC.

(54) Multiplexing plesiochronous tributaries

(57) A multiplexer for a telecommunications system is proposed which multiplexes transparently a plurality of plesiochronous sub-populated tributaries TS onto a single link. At least one of the tributaries may be from a different domain to another tributary. Typically, the tributaries are 2 Mbit/s tributaries and the link may be a passive optical network.

Fig.1a.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

Fig.1a.

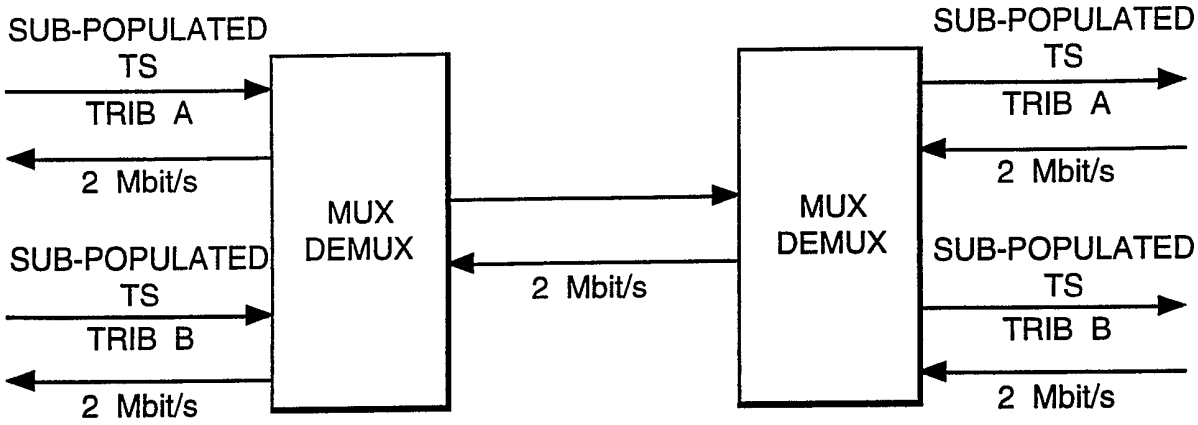

SUB-POPULATED
TS
TRIB A
2 Mbit/s
SUB-POPULATED
TS
TRIB B
2 Mbit/s
MUX
DEMUX
2 Mbit/s
MUX
DEMUX
SUB-POPULATED
TS
TRIB A
2 Mbit/s
SUB-POPULATED
TS
TRIB B
2 Mbit/s

Fig.1b.

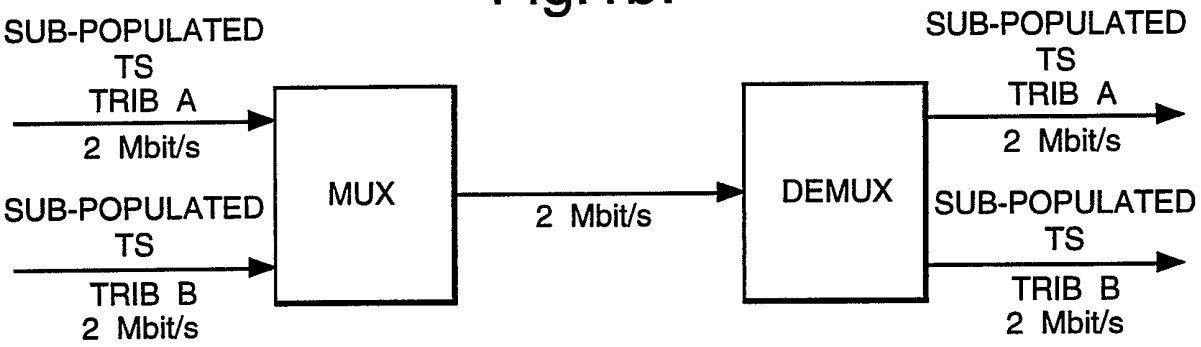
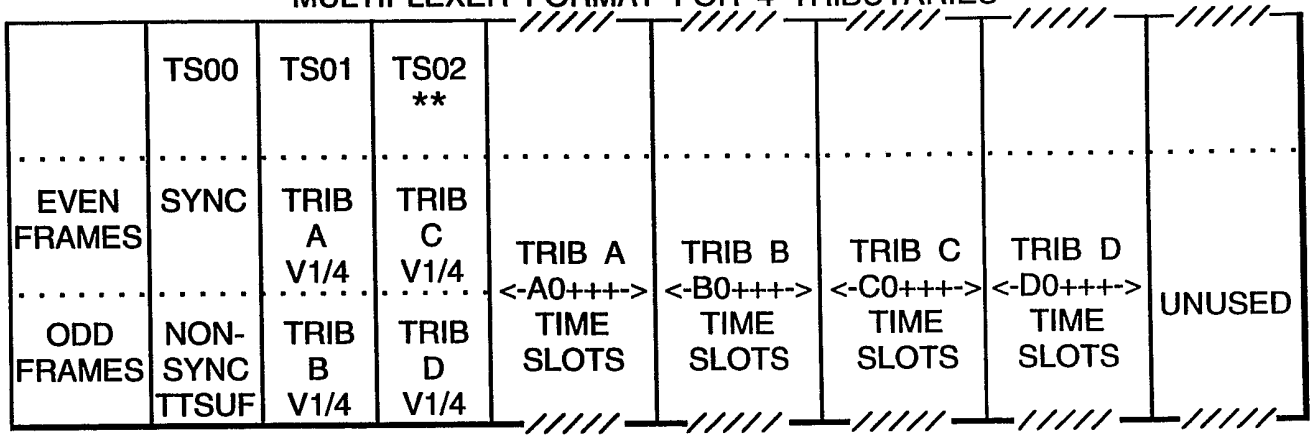

SUB-POPULATED
TS
TRIB A
2 Mbit/s
SUB-POPULATED
TS
TRIB B
2 Mbit/s
MUX
2 Mbit/s
DEMUX
SUB-POPULATED
TS
TRIB A
2 Mbit/s
SUB-POPULATED
TS
TRIB B
2 Mbit/s

Fig.2.

MULTIPLEXER FORMAT FOR 4 TRIBUTARIES



** USED FOR TRIB TIME SLOTS WHEN THERE ARE ONLY 2 TRIBS

TTSUF = TRIBUTARY TIME SLOT USAGE FIELDS

Fig.3.

SPARE BIT SIGNIFICANCE

TRIBUTARY TIME SLOT USAGE FIELDS

CRC4 FRAME	SPARE BIT 4	SPARE BIT 5 TRIB A TTSUF	SPARE BIT 6 TRIB B TTSUF	SPARE BIT 7 TRIB C TTSUF	SPARE BIT 8 TRIB D TTSUF
1	4x1 1x0	TRIB A TS 15	TRIB B TS 15	TRIB C TS 15	TRIB D TS 15
3	4x1 1x0	TRIB A TS 16	TRIB B TS 16	TRIB C TS 16	TRIB D TS 16
5	4x1 1x0	TRIB A TS 31	TRIB B TS 31	TRIB C TS 31	TRIB D TS 31
7	4x1 1x0	TRIB A 0	TRIB B 0	TRIB C 0	TRIB D 0
9	4x1 1x0	TRIB A 1	TRIB B 1	TRIB C 1	TRIB D 1
11	4x1 1x0	TRIB A 2	TRIB B 2	TRIB C 2	TRIB D 2
13	4x1 1x0	TRIB A 3	TRIB B 3	TRIB C 3	TRIB D 3
15	4x1 1x0	TRIB A 4	TRIB B 4	TRIB C 4	TRIB D 4

Fig.4.

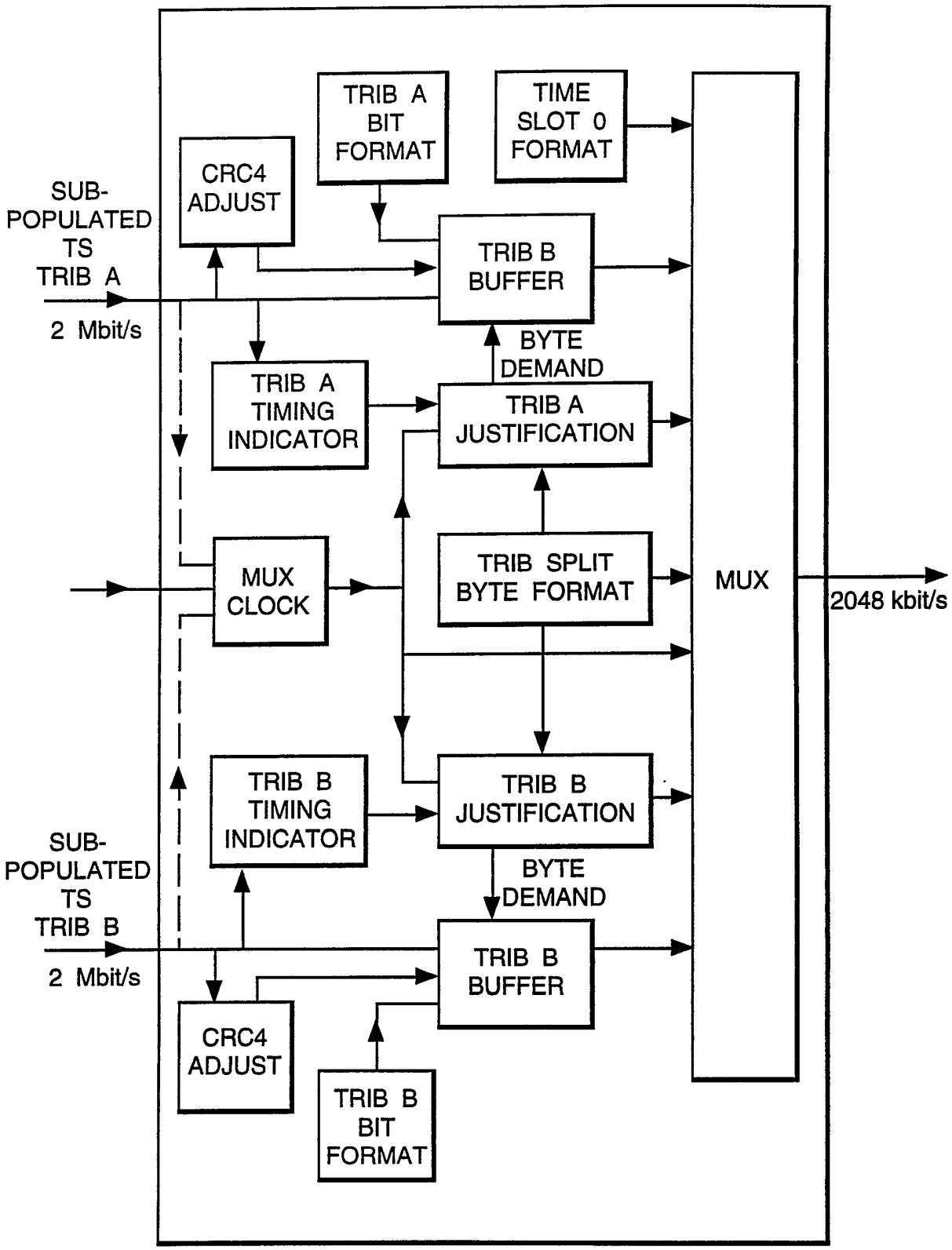
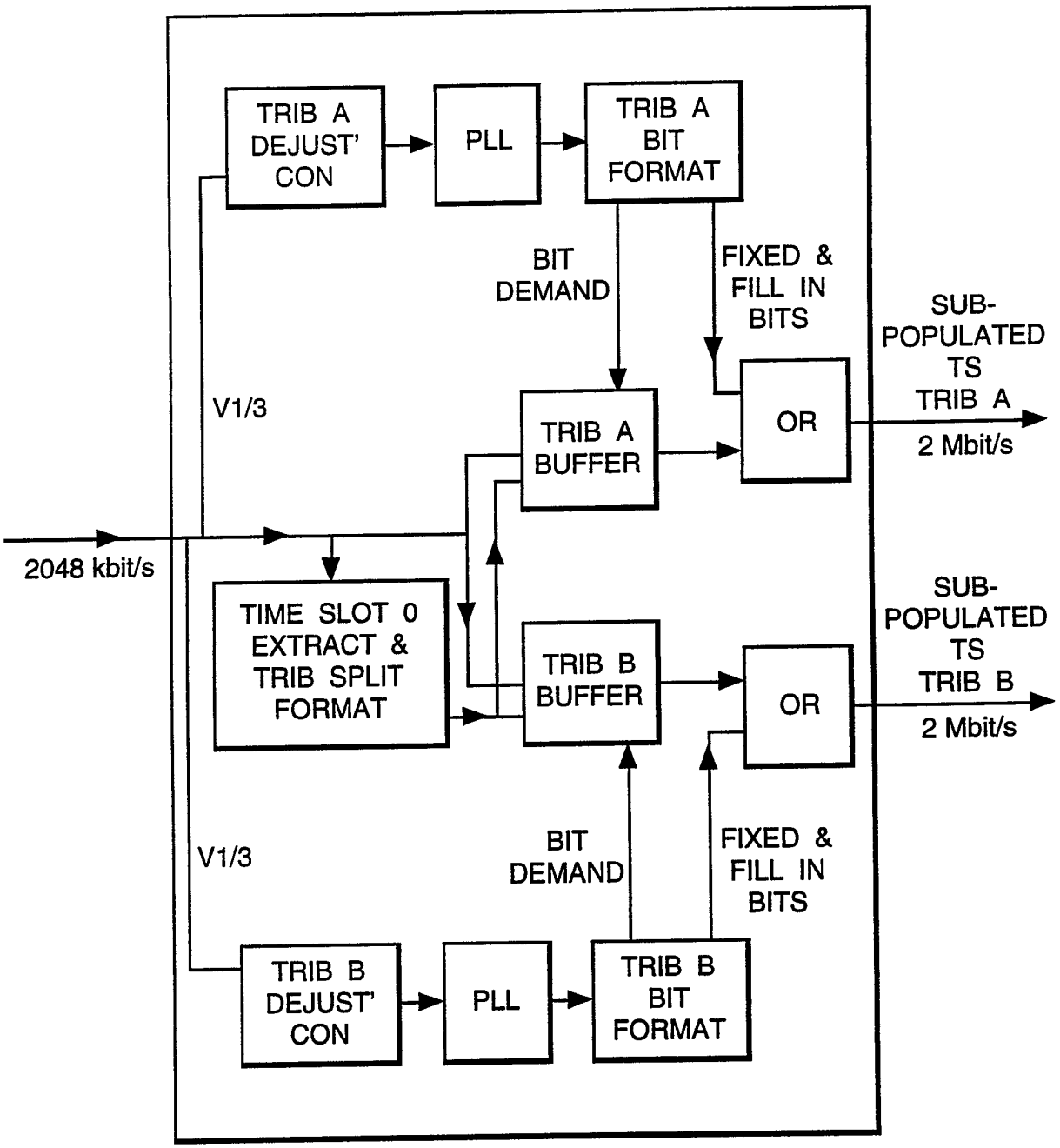

TRIB A BIT FORMAT
TIME SLOT 0 FORMAT
CRC4 ADJUST
SUB-POPULATED TS TRIB A
2 Mbit/s
TRIB B BUFFER
BYTE DEMAND
TRIB A TIMING INDICATOR
TRIB A JUSTIFICATION
MUX CLOCK
TRIB SPLIT BYTE FORMAT
MUX
2048 kbit/s
TRIB B TIMING INDICATOR
TRIB B JUSTIFICATION
BYTE DEMAND
SUB-POPULATED TS TRIB B
2 Mbit/s
TRIB B BUFFER
CRC4 ADJUST
TRIB B BIT FORMAT

Fig.5.


TRIB A DEJUST' CON
PLL
TRIB A BIT FORMAT
BIT DEMAND
FIXED & FILL IN BITS
SUB-POPULATED TS TRIB A
2 Mbit/s
V1/3
TRIB A BUFFER
OR
2048 kbit/s
TIME SLOT 0 EXTRACT & TRIB SPLIT FORMAT
TRIB B BUFFER
OR
SUB-POPULATED TS TRIB B
2 Mbit/s
V1/3
BIT DEMAND
FIXED & FILL IN BITS
TRIB B DEJUST' CON
PLL
TRIB B BIT FORMAT

MULTIPLEXER

The present invention relates to the multiplexer described and claimed in our earlier copending Application No. 9309449.8 imported herein by reference.

The multiplexer, which enables the accurate multiplexing of ATM and synchronous tributaries, is extended to multiplexing synchronous tributaries belonging to separate domains such as PSTN and private circuits by the present invention.

It should be understood that when multiplexing of a signal is carried out it is necessary to provide a multiplexer to carry out the multiplexing and a demultiplexer at the far end of the signal connection to recover the original. Additionally, to provide two way communication, a multiplexer and a demultiplexer are necessary at each end of the connection. Frequently a multiplexer and a demultiplexer are combined in a single multiplexer/demultiplexer unit.

The use of the term multiplexer should accordingly be considered as applying to a multiplexer, a demultiplexer or a multiplexer/demultiplexer as appropriate.

The earlier multiplexer is able transparently to carry one or more constant bit rate circuits, based on 2 Mbit/s, and ATM cells with one multiplex.

Typically there was a 2 Mbit/s tributary carrying time slots

zero and up to 31 other channels, with a 2 Mbit/s tributary carrying an ATM stream, into a single 2 Mbit/s multiplex and multiplexing at 34368 kbit/s and for VC3's and VC4's was described.

The present concept, like the first embodiment above, also takes a pair of 2 Mbit/s tributaries and multiplexes them onto a single 2 Mbit/s tributary.

However with the above embodiment the timing transparency only has to be maintained for the 30 channel tributary. With the present concept both tributaries are basically 30 channel tributaries requiring to be transported transparently.

According to the present invention there is provided a multiplexer for a telecommunications system comprising means to multiplex transparently a plurality of sub-populated plesiochronous tributaries onto a single link.

At least one of the tributaries may be from a different domain to another tributary.

The present invention will now be described by way of example, with reference to the accompanying drawings, in which :-

Figure 1(a) shows diagrammatically the basic arrangement of a multiplexer according to the present invention;

Figure 1(b) shows a unidirectional arrangement forming one half of Figure 1(a);

Figure 2 shows a format for the multiplexer with four tributaries;

Figure 3 shows a table illustrating the spare bit significance for the multiplexer;

Figure 4 shows a diagrammatic illustration of a two-port multiplexer structure; and

Figure 5 shows a diagrammatic illustration of a two-port demultiplexer structure.

The existing earlier described multiplexer formats could have been used, but would have prevented a hierarchy of the present concept and various time slot combinations. SDH byte justification, also Timing Indicator methods as described in Patent Application No. GB 2249002A and imported herein by reference, are also possibilities with minor variations.

The proposed method also offers transparent and plesiochronous transmission with low and constant delay, which some methods would not.

Referring now to the drawings, various formats are possible, but the following is one suggested arrangement.

The multiplexer carries up to four partially loaded or sub-populated tributaries typically each having;

time slot zero always,

time slot 15 optional,

time slot 16 optional,

time slot 31 optional,

other optional time slots starting from time slot 1.

In order to keep the delay down each tributary carried must contain at least 2 time slots (time slot zero being one.)

However the sum of all the carried time slots of the tributaries must not exceed 30. (29 with 3 or 4 tributaries).

The optional time slots (other than 15, 16 and 31) are always the lowest numbered time slots from 1 to 14 and 17 to 30.

The tributaries will be reconstructed by the demultiplexer with the normal fixed 8 bits in time slot zero and the other 8 bits are supplied to the multiplexer. The reconstructed tributaries will only contain the selected optional time slots, the remainder will usually be set to idle.

The multiplexer format is based on the normal CCITT G.703 and G.704 standard recommendations for 2048 kbit/s.

Time slot zero contains the Cyclic Redundancy Check CRC4 and CRC4 multiframe arrangements as well as using the spare bits to carry the tributary time slot usage fields.

Even Numbered Frames

TS1 used for V bytes for Trib A

TS2 used for V bytes for Trib C (if Trib C or D is carried)

Odd Numbered Frames

TS1 used for V bytes for Trib B

TS2 used for V bytes for Trib D (if Trib C or D is carried)

V bytes are based on SDH definitions V1, V2, and V3 also carries a Timing indicator.

The V byte loop operates around 8 frames instead of 4 frames for SDH.

V4 is not used at present.

The use of V bytes provides justification and provides multiplexing transparency.

The 4 bits of the CRC4 adjustment field is carried in place

of 4 of the fixed bits of time slot zero every other frame. The other four fixed bits can be used for end to end checking.

Referring now to Figure 2, time slots 2 to 31 can be associated with the Tributary A, Tributary B or left spare when only 2 tributaries are carried. Tributary A will use the first AO+++ of these time slots, Tributary B will use the next BO+++ time slots and the remainder will be left spare.

Time slots 3 to 31 can be associated with the Tributary A, Tributary B, Tributary C, Tributary D or left spare when tributaries C or D are carried. Tributary A will use the first AO+++ of these time slots, Tributary B will use the next BO+++ time slots, Tributary C will use the first CO+++ of these time slots, Tributary D will use the next DO+++ time slots and the remainder will be left spare.

A and B refer to the time slots other than 0, 15, 16 and 31. The +++ allows for one, two or three time slots of bandwidth to carry time slots 15, 16 and 31 if they have been selected.

The time slot zero format looks very much like the normal 2 Mbit/s format as described by G.704.

The format has 32 time slots, 0 to 31.

Time slot 0 has alternate frame alignment patterns.

Bit 1's of alternate time slot 0's has the CRC4 check sum and the 16 Frame, multiframe sequence.

CRC4 should of course be used to help measure the quality of the line, but the multiframe sequence is also important.

In a 16 frame sequence the spare bits, in alternate time slot 0's, are available 8 times.

Use will be made of all 5 of the spare bits, that is spare bits 4, 5, 6, 7 and 8 are used.

Individual one bit fields are required for time slots 15, 16 and 31.

A five bit field specifies the total of the other used time slots.

Because any errors in the time slot indicators would lead to the demultiplexer not recreating the 64 kbit/s circuits correctly, a majority voting arrangement is included.

Spare bit 4 follows a continuing sequence of being at logic 1 for 4 multiframes followed by being at logic 0 for 1 multiframe.

As the five copies of a time slot indicator are spaced out by 2 ms, they should not be affected by burst errors.

A multiframe (16 x 125 μs) occurs every 2 milliseconds, so 5 multiframes occur every 10 milliseconds. Therefore the split between tributary A, tributary B, tributary C, tributary D and spare time slots could be changed 100 times a second.

The CRC4 multiframe carried in time slot zero of the format defines a 16 frame loop.

This is made up of two 8 frame loops.

The justification arrangement is based on an 8 frame loop.

Over an 8 frame loop each tributary has,

Byte 0 [From TS0 (1 + 7 bits) +
CRC4 adjust (4 bits) + (4 other bits)] x 4 = 8 bytes
From N time slots N (8 bits)x8 = N x 8 bytes
Total is (1 + N) x 8 bytes

When n = 29 (only 1 tributary) total is 240 bytes

Consequently the pointer range has to change when the multiplexer tributary time slot usage fields (TTSUF) are changed. In practice this requires some careful phasing in order to prevent corruptions occurring.

For delay reasons a minimum of one time slot plus time slot zero must be carried from each tributary.

The time slots which are not carried by the link are replaced with idle patterns, by the demultiplexer, with the exception of time slot 30 at the end of each 2 frame loop (No tributary format should use time slot 30). The last 4 bits of this time slot (5, 6, 7 and 8) are replaced with the 4 bits of the CRC4 adjustment field. This is to ensure that the CRC4 bits in the next frame loop will not produce an error if no corruptions have occurred since the tributary was originally formed.

The other 4 bits of time slot 30 could be used to indicate responses to a tributary if the domain control mode is used.

In order to achieve this, each unwanted time slot is discarded at the multiplexer end, the discarded time slot is compared with the idle pattern that will eventually replace it, this is done for all such channels in order that the appropriate CRC4 adjustment field can be generated.

The technique is described as having two similar, but independent, unidirectional parts, see Figures 1 and 2, and it can still operate in that manner when required.

It is also possible to say that in many (if not all) circumstances the two directions will have the same time slot usage for the tributaries, in which case, if one end is declared as the Slave end, then the Slave end can be told to multiplex the tributaries with the same time slot usage as defined by the tributary time slot usage field it receives from the other end of the link. It is probably not advisable to tell the other end it is the Master end as it must still decode the tributary time slot usage fields it receives from the Slave end in order to ensure changes to the time slot usage are done in a synchronised fashion.

Although the time slot indicators allow dynamic reallocation of the bandwidth, releasing a time slot from one tributary does not mean that the other tributary can instantly take advantage of it as with the earlier multiplexer.

In the earlier multiplexer the ATM tributary can make use of any extra bandwidth by lowering the delay imposed on the cells and it allows the ATM to mop up any spare bandwidth from any unused time slots spread amongst the used time slots provided that the ATM tributary does not complain when it loses the bandwidth again. Because ATM is not a transparent multiplexing method, any circuits carried by ATM must expect changes in service performance.

The present multiplexer however would normally work with a very defined split between say the PSTN and Kilostream. To move a circuit would require a management action to take a time slot out of service from one domain, and make it a spare, before it could then be placed into service in the other domain.

In many cases there may only be say 10 PSTN and 7 Kilostream circuits in use anyway, so if the sum of the circuits does not reach 29 then the spare time slots can be left as spare, or some could be allocated to the tributaries. The important point being that only one 2 Mbit/s transmission link has to be used.

Consequently, unlike the earlier multiplexer, the monitoring of time slot 16 messages is not thought to be an advantage.

The transmitted tributary time slot usage can be controlled by;

management interface	(external mode)
switch settings	(manual mode)
received Spare bits from one of the domain tributary interfaces	(domain mode)

received Spare bits of the
multiplexer (slave mode)

Where a pair of 30 channel systems are multiplexed it may seem very simple to say time slots not used by one domain can be used by the other. However several synchronisation questions had to be addressed.

If one tributary is used to supply the timing then the other may see

slips,
CRC4 errors
loss of frame alignment
loss of timing transparency
total failure when the synchronisation tributary falls,
depending on which compromises are used.

Although the multiplexer described has internal complexity, the techniques are all known and can be fitted into Application Specific Integrated Circuits (ASICs). Because the multiplexer does use accurate justification techniques, it should not cause any management problems provided the domains can operate with some time slots being out of service.

The arrangement will operate with plesiochronous 2 Mbit/s tributaries.

The multiplexer can work from either tributary clock, or an external clock or an internal crystal.

The multiplexer uses its chosen clock source to drive an internal oscillator running at 16,384 kHz. This is divided down to give 8 kHz, 4 kHz, 1 kHz and 500 Hz; frame, double frame, 8 frame and 16 frame loops.

The 4 kHz is used to sample the arrival of tributary time slot zeros with frame alignment signals in order to generate Timing Indicators on a 4 kHz base to 61 nanosecond accuracy. The timing indicator therefore has 12 bits. The two bytes of a timing indicator carried by V3 are in fixed positions in the 16 frame multiframe.

Because the multiplexers and demultiplexers have to work plesiochronously each unit has several separate asynchronous areas.

To make the asynchronous working easier similar data is held in several places.

In the multiplexer, because 7 bits and 1 bit have to be carried for time slot zeros along with 4 CRC4 adjustment bits and 4

other bits the tributary buffers are loaded with one byte at a time. Similarly in the demultiplexer the tributary buffers are emptied by one byte at a time.

The multiplex interfaces into the Tributary buffers always work in byte mode and therefore use a byte justification scheme.

Considerable care has been taken with the arrangement to make it as transparent as possible.

Because of the way that the tributary time slot usage fields are defined the formats for the individual tributaries and the multiplexer link can all be deduced from the information carried in spare bits 5, 6, 7 and 8.

With the exception of time slots 15, 16 and 31 the tributaries use the lower numbered time slots first.

The format uses the time slots with low numbers in preference to those with high numbers.

Consequently a formatted link is capable of being a tributary into another multiplexer. A single multiplexer permits 4 tributaries, each using 7 time slots (including time slot zero), to be transparently multiplexed into one 2 Mbit/s link. Two multiplexers, each with 4 tributary inputs and each carrying 3 time slots (including time slot zero), can be further multiplexed into one link. Many other combinations are also possible.

Buffering delay will be incurred at the multiplexer and demultiplexer tributary buffers. Because justification is used, and not frame aligners, the buffers have to be sufficient to overcome the variations introduced by the format jitter and justification jumps.

Because Timing Indicators are used the buffers are made to track a defined point near the centres of the buffers and therefore give a constant delay.

The constant delay is defined to ensure that the buffers never become totally empty. By making the buffers long enough there is no chance of overflow.

Because of the 1 frame bandwidth loop, a constant one way delay of one frame plus a few microseconds should be sufficient to cover all multiplex options, provided at least two time slots (including time slot zero) are carried by a tributary.

It can be assumed that all the interfaces can be physical 2048 kbit/s HDB3 links. However the mux/demux could be subsequently integrated into a larger function, with just the formatted link

remaining as HDB3 or even this being carried by an SDH VC12.

Carrying the current multiplex in a VC12 is interesting in itself as the container is larger than 2048 kbit/s and therefore more than 29 time slots could be handled.

Integration can lead to testing and management problems. Maintaining the clear boundaries between the different domains of networks is essential.

When transmission costs are high, multplexing becomes attractive. Multiplexing that is not transparent causes many problems.

A transparent multiplexing method for reducing 2, 3 or 4 off 2 Mbit/s tributaries down to one 2 Mbit/s transmission link has been described, provided the total number of time slots to be carried (including time slot zeros) is not greater than 30 for a pair of tributaries and 29 for 3 or 4 tributaries. CRC4 and other non-fixed bits of time slot zero are carried transparently. The formatted links are suitable for taking into the tributary inputs of a further similar multiplexer.

The total loop delay incurred should be less than 300 us.

Bandwidth is only free when it is plentiful and there is little demand.

Sub-Populated 2048 kbit/s links, may seem to be a very inefficient way to use bandwidth. However if Sub-Populated 2048 kbit/s links are viewed as a standard interface, where there are no unfortunate consequences if the unused channels are not transported, then several opportunities arise.

In order to take full advantage of these opportunities, it is necessary to recognise the many areas where sub-populated 2048 kbit/s do occur, or could be arranged to occur.

Also, in order to minimise the network management problems the domain segregation must be maintained.

A sub-populated 2048 kbit/s link has a normal time slot zero, some used time slots and some unused time slots. It was suggested above that the used time slots are the lower numbered time slots and that time slots 15, 16 and 31 can be used as required.

The following examples of Sub-Populated 2048 kbit/s show where the 2048 kbit/s bandwidth is often not fully used.

EXAMPLE 1 - Sub-Populated DASS

If some of the time slots are not required on a DASS (or V5.2 or CCITT equivalent Q.931) 2048 kbit/s Interface to a PABX, then this

could be declared as a sub-populated DASS interface.

EXAMPLE 2 - Sub-Populated DPNSS

The DASS format was derived from the DPNSS format. Therefore a private network operator could declare that certain time slots of a DPNSS 2048 kbit/s link are not used and so create a Sub-Populated DPNSS link.

EXAMPLE 3 - Sub-Populated Cellular Radio Base Station 2048 kbit/s Link

A cellular radio Base Station often does not use anything like 2048 kbit/s of bandwidth on a link back to a mobile switching centre. So a Sub-Populated 2048 kbit/s link could be defined for this example.

EXAMPLE 4 - Sub-Populated Message Based 2048 kbit/s (ATM)

Message based links are automatically unused when there are no messages to be passed. Just because 64 kbit/s (kilostream) and 2 Mbit/s (Megastream) are the normal bit rates offered by the operators it does not automatically follow that they are the peak bit rates most appropriate for their customers.

When a peak bit rate lower than 2048 kbit/s will suffice, provided a time slot zero is provided and only a defined number of time slots are used, then a Sub-Populated Message Based 2048 kbit/s format can be arranged. The term compressor unit is used for the function to format a sub-populated stream from a 2048 kbit/s link which has considerable regular ideal time. (The compression ratio can be changed dynamically as described in Bandwidth on Demand later.)

EXAMPLE 5 - 384 kbit/s circuit (Private Circuit)

This example is a 384 kbit/s channel (6 x 64 kbit/s) and a time slot zero, with all the other time slots not being used.

Other circuit rates could be handled in a similar way if they are required. (For example for carrying several 384 kbit/s channels.)

EXAMPLE 6 - Sub-Populated Kilostream Carrier

64 kbit/s kilostream circuits are carried on 2048 kbit/s links. Such links are not always fully populated. Therefore there are many Sub-Populated Kilostream Carriers already in use.

EXAMPLE 7 - Sub-Populated 2048 kbit/s with Signalling in Time Slot Zero

Kilostream does not use time slot 16 for signalling, but DASS and DPNSS do. For a sub-populated link, 2 spare bits in time slot zero, may be enough to supply an 8 kbit/s signalling channel, or 4 spare bits for a 16 kbit/s signalling channel. This would mean that one less time slot would need to be carried. (Using 4 spare bits would

prevent the Bandwidth on Demand algorithm described later being used at the same time)

There are three identified techniques that can take advantage of Sub-Populated 2048 kbit/s. These techniques can be combined in many ways for different applications.

There are three identified techniques that can take advantage of Sub-Populated 2048 kbit/s. These techniques can be combined in many ways for different applications.

Work has been done for some time on delivering several channels on a copper pair via the local copper access networks.

The number of channels that can be carried is dependent on several factors such as the length of the copper path and the weight of the copper conductors used.

Rather than having a multiplicity of multi-channel interfaces that customer premises equipment must be able to work to, it would seem sensible to standardise on one multi-channel interface, namely the 2048 kbit/s interface, but with only some of the channels used. The carrier used on the copper is reduced from 2048 kbit/s so that only the used channels are carried.

All the Sub-Populated examples listed earlier can be carried by such a Reduced Bit Rate Carrier, provided sufficient time slots are provided.

There are several formats that a reduced bit rate transmission system could use.

The formats used for carrying the multiplex above (but with only one tributary) would be a satisfactory basis. This method would incur an overhead. More efficient methods can be considered for this special case in order to save a time slot, but certain aspects may be lost, such as CRC4 transparency and fault detection.

The basic multiplexer described above takes a pair of sub-populated plesiochronous 2048 kbit/s G.704 interfaces and multiplexes them together into one 2048 kbit/s link, provided that the total number of time slots (including time slot zero) of the two tributaries to be carried is less than 30.

Such a 2048 kbit/s multiplex is suitable to be a tributary in another multiplexer (of course second order multiplexing adds more delay).

The multiplexer uses justification methods in order to accurately carry plesiochronous tributaries.

Without recalculating the tributary CRC4, some of the data carried in unused time slots is adjusted to ensure effective end to end transparency.

Any change to the number of time slots allocated to a tributary is indicated to the demultiplexer end 5 times over before being acted on. Master/Slave working is also catered for.

The multiplexer described above is based on a 2 Mbit/s transmission rate and shows how 4 plesiochronous tributaries can be directly carried in one 2 Mbit/s link used as synchronous byte transport mechanism.

The technique can be used for higher bit rate carriers of multiple 64 kbit/s channels.

A Passive Optic Network (PON) can be regarded as carrying a synchronous byte transport mechanism. Therefore a PON can be used to carry many sub-populated plesiochronous tributaries.

A PON may use a Time Division Multiple Access (TDMA) over a 2 Frame loop.

Therefore based on the multiplexer, which has a quite uniform data flow, and based on a 2 Frame PON loop the minimum subscriber message is 5 bytes per two frames (with time slot 1 used in the example below).

V Byte	[V1, V2, V3, or V4]
4 Payload Bytes normally containing	
Even Time Slot Zero	BIT 1 carried
	Sync pattern removed
	4 bits of CRC4 adjustment
	3 unused bits
Time slot 1 byte	
Odd Time Slot Zero	All but BIT 2 carried
	1 unused bit
Time slot 1 byte	

Because of justification reasons occasionally one byte may be empty or the V3 byte may be full.

V1/2 SDH type pointer with Timing Indicator in most V3 bytes.

The V4 byte can be used for the control of the customer premises P-PON unit (e.g. ranging).

The 4 unused bits may be required for other purposes such as an SDH type of Path Overhead.

At the customer premises a Plesiochronous PON (P-PON) unit would be able to support several sub-populated plesiochronous 2 Mbit/s interfaces.

From the above format it should be noted that if a fully-populated plesiochronous 2 Mbit/s is to be carried, then the complete 32 time slots can be carried, as an unstructured bit stream, using the same justification scheme in the V bytes.

Therefore the customer premises P-PON unit would be able to support fully-populated unstructured 2 Mbit/s interfaces and sub-populated plesiochronous 2 Mbit/s interfaces.

The Bandwidth Allocation can be controlled by spare bits in time slot zero from the Tributary interfaces themselves.

This could be done using similar control formats to the Tributary Time Slot Usage Fields (TTSUF) employed by the multiplexer.

A 5 Multiframe Loop would still be used to protect against errors, indicated by spare bit 4. The inverse sequence is used to show that these are tributary formats rather than multiplexer formats.

There would be a Demand New Time Slot Usage Field (DNTSUF) in spare bit 5.

There would be an Accepted Time Slot Usage Field (ATSUF) in time slot 30.

There would also be a Reflected Time Slot Usage Field (RTSUF) in spare bit 6.

The method of operation is that;

the tributary will indicate via the DNTSUF what bandwidth is demanded,

the multiplexer or P-PON will respond via the ATSUF in time slot 30 to state what allocation is accepted,

the tributary will reflect the ATSUF in the RTSUF.

The RTSUF allows a tributary at one end to indicate to the tributary at the far end how many time slots are in use.

This bandwidth of demand technique does not require dynamic response of Central Network Management for each change in allocation. This local dynamic interworking interface is a simple and practical method of achieving bandwidth on demand, because it does not cause the various domains to become muddled.

The access domains of operators need to carry an increasing number of 2048 kbit/s megastream circuits for private networks, as well as the 2048 kbit/s links for their own service networks.

A great many of these 2048 kbit/s links are not fully populated as the earlier examples have shown.

If the Sub-Populated 2048 kbit/s links are recognised as Sub-Populated, by both the access network and the private/service networks then the Three Techniques Reduced Bit Rate Carrier, multiplexer and P-PON can be employed as appropriate. In some circumstances more than one can be employed.

Where the Tributaries are from different domains, the Reduced Bit Rate Equipment, multiplexer and P-PON will be owned and administered by the access domain.

It is also possible to deploy the multiplexer within service Networks. It can avoid the need for grooming equipment in Cellular Networks to minimise the number of leased 2048 kbit/s circuits. It can also be used for combining DASS links together from PABXs on adjacent sites, and for combining sub-populated kilostream carriers.

In these cases, because the tributaries belong to the same domain, the multiplexer can be owned and administered by the Service Network.

It is also possible to deploy the multiplexer within private Networks, because EXAMPLES 2, 4 and 5 are all carried on leased 2048 kbit/s circuits. Therefore any leased 2048 kbit/s circuit could be used to carry two or more sub-populated 2048 kbit/s, time slot usage permitting.

In this case the multiplexer can be owned and administered by the private network concerned.

Several Sub-populated DPNSS links can be carried on one Megastream Circuit. In this case the multiplexer could belong to the private network domain. It is also possible that the operator would supply and operate them in the access domain. Because they can be cascaded, some 2 Mbit/s that have been multiplexed in the private domain can be further multiplexed in the access domain.

The rule of course is that the complementary demultiplexer must always be in the same domain as the multiplexer.

A multiplexer as above can multiplex any type of Sub-Populated 2 Mbit/s links (DASS, DPNSS, ATM, Kilostream, etc.)

A small business using say 4 PSTN channels (+TS0 +TS16) on a 2048 kbit/s DASS link and 3 kilostream channels (+TS0) on another 2048 kbit/s link, could have the 2 sub-populated 2048 kbit/s links multiplexed together using such a multiplexer and the resultant 12 time

slots carried on a 768 kbit/s reduced bit rate copper transmission system on just one pair.

Business traffic can be consolidated onto the available local transmission, whether it is 2 Mbit/s on copper, 2 Mbit/s over SDH, reduced bit rate or P-PON.

Where several transmission links will be used by a business. It is possible to split the traffic from one service into two and carry it in separate sub-populated access routes for security.

A business which finds that it now needs a few more channels and its 2 Mbit/s link is full could use the reduced bit rate method to carry the excess.

A business with 4 PABXs, say A, B, C and D could lease a total of 3 Megastream links from central site A (one to each of the other sites). Using the above multiplexer each megastream link could carry 3 DPNSS routes so that each PABX appears to be directly connected to the other 3 PABXs. Where there are several other types of connections, Data, Video Conference, etc. the options become considerable.

Because Sub-Populated 2048 kbit/s are carried in a fully plesiochronous manner the synchronisation problems that many private networks run into when using 64 kbit/s crossconnects can be avoided.

One operator offering a sub-populated megastream, DASS and Kilostream services could cut their access costs and therefore price in order to undercut another operator.

The advantages of formally recognising the existence of the many Sub-Populated 2048 kbit/s links already in service, will permit advantage to be taken of the above multiplexer as well as the Reduced Bit Rate technique and the Plesiochronous PON. It will also enable the sub-populated Megastream service to be introduced.

The opportunity for Bandwidth on Demand, without the need for a dynamic network management response, is considerable as it avoids the problems of interacting the management functions of the different services with the management of the transmission and access networks.

Because all the techniques preserve the timing transparency of the sub-populated links, they can be widely applied, compared with other techniques.

The multiplexers described in GB 9309449.8 referred to earlier were mixing constant bit rate circuits and ATM on various carriers.

One such multiplexer was mixing a pair of 2 Mbit/s, one of which carried a message based multiplex such as ATM.

This function can be carried out using the present multiplexer by taking the ATM tributary via a compressor unit, which restricts the number of time slots used to carry the cells, prior to the multiplexer. The output of the compressor unit is a sub-populated 2 Mbit/s. The compression ratio could be fixed or variable. The compression ratio could be controlled by the amount of spare bandwidth not used by the 30 channel tributary such as in the earlier application.

Therefore the present multiplexer can incorporate the earlier requirements for 2 Mbit/s tributaries.

The principle of the present multiplexer can be used to multiplex ATM tributaries together. In this case the split between the ATM tributaries could be controlled by the recent history of the fill levels of the input buffers.

As long as the format of the ATM or any message based format is recognised and to a standard, then a compression unit can be designed and multiplexing achieved.

With the correct compression units any message based formats can be multiplexed together, which could be very useful in certain private networks.

CLAIMS

1. A multiplexer for a telecommunications system comprising means to multiplex transparently a plurality of sub-populated plesiochronous tributaries onto a single link.

2. A multiplexer as claimed in Claim 1, wherein at least two of the tributaries may be from different domains.

3. A multiplexer as claimed in Claim 1 or 2, wherein the integrity of the Cyclic Redundancy Check (CRC4) is maintained end to end across the tributaries.

4. A multiplexer as claimed in Claim 1, 2 or 3 wherein the tributaries are 2 Mbit/s tributaries conforming to CCITT G.703 and G.704 and the total number of time slots to be carried by the single link is less than 30.

5. A multiplexer as claimed in Claim 4, wherein the tributaries carry data in time slot zero and at least one further time slot.

6. A multiplexer as claimed in Claim 5, wherein the further time slots are selected from time slots 15, 16 and 31 and subsequently the lowest numbered time slots from 1 to 14 and 17 to 30.

7. A multiplexer as claimed in Claim 5 or 6, wherein the time slot usage is identified by the use of the spare bits in time slot zero.

8. A multiplexer as claimed in Claim 1, wherein the link is a passive optical network.

9. A multiplexer as claimed in any preceding claim, further comprising a majority voting arrangement to identify the used time slots.

10. An arrangement of two interconnected multiplexers, each as claimed in any preceding claim, wherein the output of a first of the multiplexers provides a tributary input to the second of the multiplexers.

11. An arrangement of two interconnected multiplexers, each as claimed in any preceding claim, wherein the multiplexers operate in a master/slave relationship.

12. A multiplexer as claimed in any one of Claims 1 to 9 or used in an arrangement thereof as claimed in Claim 10 or 11, wherein the bandwidth allocated is controlled by the use of spare bits in time slot zero from the tributary interfaces.

13. A multiplexer as claimed in Claim 1 and substantially as hereinbefore described, with reference to and as illustrated in the accompanying drawings.

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Examiner's report to the Comptroller under Section 17 (The Search Report) -19-

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Relevant Technical fields

(i) UK Cl (Edition L) H4M (MTP1, MTP2, MTP3, MTCA1, MTCA2, MTCA3, MTCX1, MTCX2, MTCX3, MN)

(ii) Int Cl (Edition 5) H04J

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MR S J L REES

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI, INSPEC

Date of Search
30 SEPTEMBER 1993

Documents considered relevant following a search in respect of claims 1-13

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2204764 (GEC) Whole document	1
A	US 4807221 (SIEMENS) Whole document	1

		Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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