Packet switched optical router

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Our laboratory is a participant of an international project where an optical core router development and research is made by university and industry members. The developed hardware based on wavelength division multiplex and subcarrier label technology. The concept, the stage of the development and the foregoing results will be demonstrated below very briefly.

Our laboratory is member of an European 3 years long project, called LABELS, where in optical backbone applicable core router will be developed. The participants are universities, manufactures and operators. Because of the research is not only theoretic but experimental also, the aim is to build and test a prototype. Our part is to realize the optical address processing unit.

The concept and the foregoing results will be detailed below.

Concept and specification

Relation to the design and specification of the device the next criterions were respected:

Because of the high speed WDM network application, the speed of the device was chosen to 10 Gbit/s per channel.

Other important respects were the testability and the cost effectively. Therefore minimum 8, maximum 16 channels routing are implemented.

Because of the IP network transparency and the available technology, O/E conversion and subcarrier label were used [2,3]. The various packet lengths take for the high speed 300 Mbit/s optical label. At this speed, in burst mode, the router device has to finish the label recovery and routing process along 1-2 µs. This time is given by the next calculation:

Because of the IP network transparency, we can calculate with 1500 byte long packets in average. Until the label processing the data packets are delayed by an optical delay line. This delay line is implemented by a few 100 m long optical fiber. The propagation speed in a fiber is n_1/c, where c is the velocity in vacuum ($3*10^8$ *m/s*), and n_1 is the refraction index of the fiber core. In the monomode fiber $n_1=1{,}45$. If the fiber length is L=400 m, the delay time is T=L n1/c=1.93 µs. The delay line length must be so calibrated, that the longest packet must be shorter in time than the delay line.

The label structure will be detailed in the next chapter. The specification has to involve the optical filters and the photodetector parameter, and the collision detection's method. The optical filter is a critical part of the system because of the required narrow band operation. The applied filter should be able to separate the subcarrier. While the distance in spectra between the baseband signal and the subcarrier is only 10 GHz, the optical filter must be very narrow band. The O/E conversion is made by an envelope detector. After the detection, the arisen baseband signal is processed by the label recovery circuit.

In case of collision the lower priority packet will be dropped by a collision detector. Based on the above detailed parameters the structure of the device and the label can define.

Optical address

In our case one channel is equal with one wavelength. The intensity modulated data speed is 10 Gbit/s. 20 GHz distance from the data in spectra can be found the NRZ (non return to zero) coded optical label information. The speed of the label is 300 Mbit/s. The optimal address length determination depends on 3 aspects:

- The address length should be enough to the synchronization because of the data recovery process. In case of open loop structure, based on the measurements 128 bits are needed for the safe synchronization. At the closed loop solution, this value is much more less. The preamble length can be reduced for 2-3 bytes. The drawback of the closed loop structure is the usage of the PLL. Because of this drawback, in our case the open loop recovery was used.
- The duration of the effective label information and the preamble together must be less than the 45% of the process time. If the duration of the 1500 byte length packet is 1,2 µs, and 100 ns time-protection is used for the elimination of the packet and the label overlapping, the available label recovery time is 450 ns. In this case 128 bits optical address can apply. For the routing process 600 ns additional time is available.

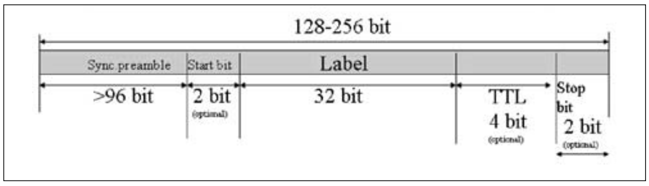


Fig 1. Optical address

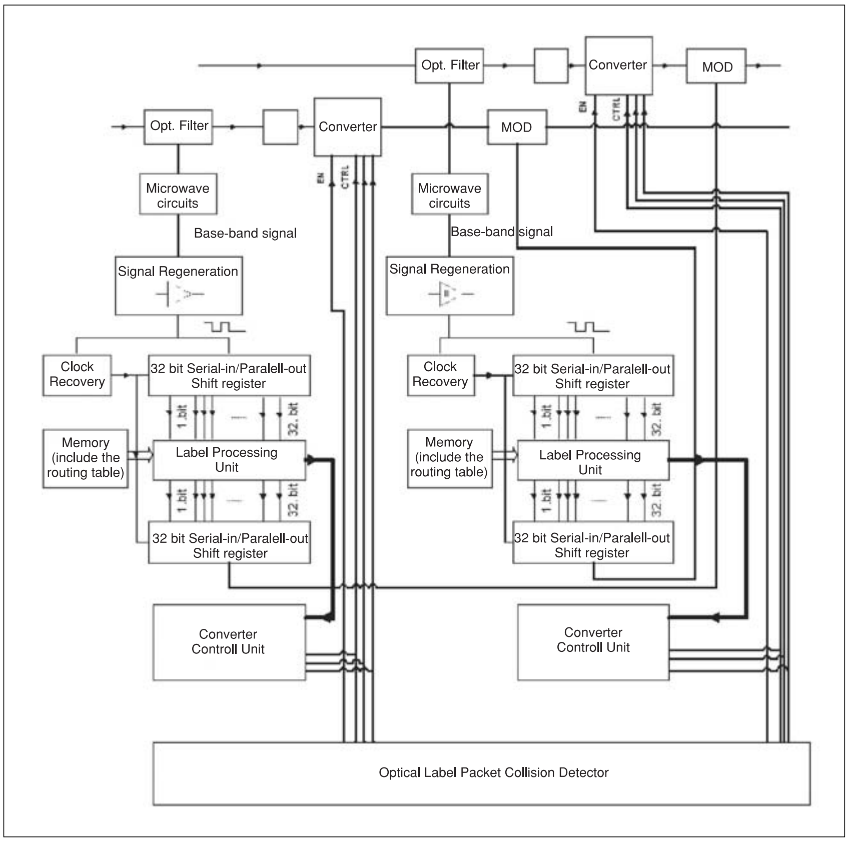
- At last the label contains start unique words to identify the beginning of the effective address information and TTL (Time to Live) bits to avoid the loop in the network. Because of the optical labels valid in the optical networks only, the 32 bits result adequate unique address *(Fig. 1)*.

Router structure

The developed router with two channels is illustrated by the *Fig 2*. At the input the incoming wavelengths are separated by a multiplexer to different channels. After the channel separation the optical label information is outfiltered. The data payload goes through an optical delay line in the same format.

During the delay time the optical label process must be done. The new optical label is generated, and the control logic sets up the wavelength converter. After the wavelength conversion (routing process) regenerated label information will be up-mixed and modulated on subcarrier of the packet carried on a new wavelength.

Fig 2. Two channel router block diagram



The chronologic order of the label process is the following:

The outfiltered optical label information is converted to a baseband electric signal by an envelop detector. The effective information will be recovered by using an open loop structure. Based on the effective label information and the static routing table the wavelength converter setup will be done. The optical label will be regenerated in the given format. The collision detection is based on packet priority.

The next chapter below details the open loop data recovery method.

Digital control logic

The open loop data recovery process made by an FPGA based (Field Programmable Gate Array) [1]. Because of the low cost, the high flexibility and the relatively high speed (in our case clkin = 420 MHz) the FPGA is able for network applications. The two main part of the control circuits are the user interface and the label processing unit.

The open loop data recovery based on an oversampling. The incoming bitframes are oversampled by a latch matrix. The elements of the D-latch matrix are divided by the clock and its phase shifted domains (90°, 180°, 270°). The oversampling structure is illustrated on the *Fig. 3*. The four phases results 4 time domain.

The right bit detection is made by a bit transition detector and time domain selection circuits. Because of the jitter the time domains are five latches long (Fig. 3). The bit transition detector selects the right time domain. The given data bits go through a serial/parallel transformation and after this are processed by a comparator. The beginning of the address information is signed by a special unique word. After the unique word matching the following 4 bytes are stored by a memory as the optical label information. The new wavelength is determined by the routing table. Finally the optical label is regenerated in the Fig. 1. which shows format, and added by an external microwave modulator to the subcarrier of the data packet.

Results and problems

At this moment the BER (Bit Error Ratio) measurement are on. To the BER measurement both transmitter and receiver circuits are needed. The optical address in predetermined format is generated by the transmitter circuit.

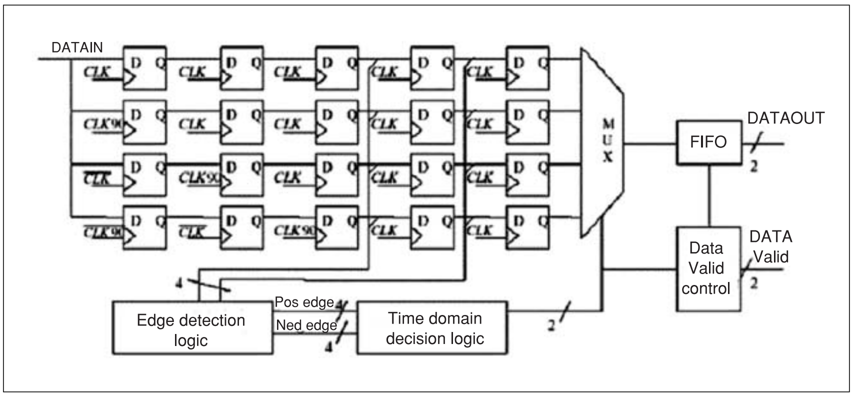


Fig 3. Data recovery

The transmitter includes random number generators (RNG). The random addresses and the random time between the packets are generated by the RNGs. The receiver recovers the burst mode label packets and stores the results. The BER is given by a comparator circuit. The asynchronous connection was simulated by using of different clock signal in both the transmitter and in the receiver. The clock frequency difference was a few MHz. The clock frequency of the transmitter was 200 MHz, and the receiver's clock frequency was tuned around 200 MHz ± 5%.

The synchronization time in function of the transmitter's clock ad the length of the preamble are illustrated on the *Fig 4.*

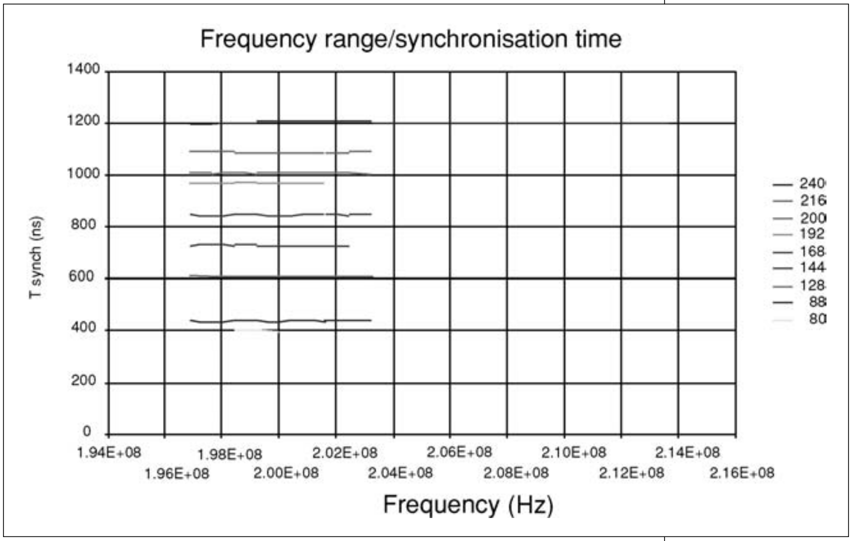


Fig 4. Measuring result

The minimal preamble length is 88 bit, and the minimal recovery time is 400 ns. The maximal possible frequency difference between the receiver and transmitter clock can be 2,2 MHz. It means 10% tolerance. This tolerance much more higher, than the requirements in the asynchronous networks.

At this moment our system fault are the maximum label recovery speed and the static routing.

Not faster than 200 MHz speed optical label can be recovered by the device.

In the future 300 MHz will have been achieved by the optimization of the digital circuits.

Only a static routing table can be used because of the available computing speed. The usage of dynamic routing table needs much more complex structure.

The developed device is capable only for wavelength routing. The physical routing is not supported. The physical routing can be achieved by using of 2 level structures, wherein the basic level is the wavelength router. In this case the wavelength routers are managed by an optical switch matrix.

Conclusion

We hope that we were able to give an adequate overview about our topical optical signal processing research.

We rely on that we find the solutions of our problems whereby other new questions and results could be finding up.

Believe the optical networks, it is the future!

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