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Efficient Management of Lightpaths in WDM Optical Networks Employing Multiple Wavelengths Concurrently during Setup

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g the same wavelength reserved in all
h, is called a lightpath. Lightpath

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ves three basic steps: (i) routing, (ii)
and (iii) wavelength reservation. Here
ked shortest path routing. However the
re may use other routing methods also.
n of wavelength (for reserving it later)
use it indirectly affects the sharing of
resource in WDM networks) and hence
Requests are normally blocked due to
elengths. But blocking may also occur
two or more requests try to reserve the
ut noticing the other free wavelengths.

nethods are used for selection of
ation, two conventional methods are:
5]. In random-fit, a wavelength is
n the available pool of wavelengths. In
s are indexed in an order, and the
e lowest index is selected from the
elengths for reservation. In another
ngth selection is done using label
e the priorities of wavelengths are set
uration of stay in the pool. Another
thod is using Markov model. A notable
sed Backward Reservation Protocol
his method for selection of wavelength.

of wavelength is done using Markov
on is done using Destination Initiated
DIRP). Here, a wavelength is guessed
well in advance, so that other requests

do not select that guessed wavelength. Thus, wavelength conflict among contemporary requests is reduced. Consequently, MBRP performs better than DIRP [10]. In Markov based Split Reservation Protocol (MSRP), wavelength

Aggressive reservation is also used on SRP, which is

If RES_BKD successfully reaches the *source*, then at *source*, it waits for ACK of RES_FWD. If RES_FWD reaches the *destination*, with nonempty *reserve_set*, then an ACK is sent towards *source* along with the *reserve_set*. ACK, on its way,

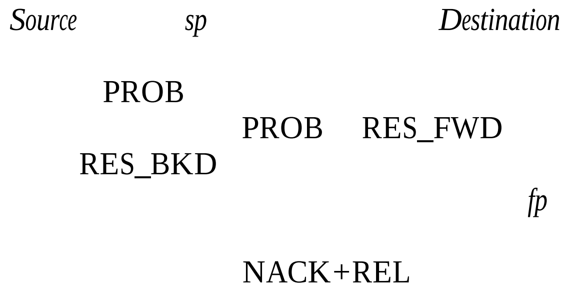

Fig.6: Failure of RES_FWD in SRP

keeps a copy of the *reserve_set* at *sp*. After receiving the ACK, the source checks the matching of the wavelength reserved in forward and backward directions. If those are matched, the data transmission starts (Fig.5). If there is mismatch in wavelength reservation or if RES_BKD fails, then RES_BKD is converted into REL_FWD which moves towards sp releasing the reserved wavelength. At *sp*, REL_FWD randomly selects another wavelength from the *reserve_set* for retry, and becomes RES_BKD again. This is repeated (if required) until total number of retries (*b*-1) is exhausted. If RES_FWD is stuck before *destination*, then it is the case of failure (Fig.6) and it is converted into NACK_REL. The NACK_REL moves from the *intermediate node* to the *source*, and releases the wavelength reserved by both RES_FWD (from the node where failure takes place to *sp*) and RES_BKD (from *sp* to *source*). After receiving the NACK_REL at *source*, the request is blocked.

Performance of SRP is compared with its peer IIRP. Single wavelength is used for reservation in SRP, to keep parity with IIRP, and the simulation results obtained is shown in Fig. 7. From the figure, we find that, for both the schemes, *bp* increases with cr due to increase in crisis of wavelength. Also, we see that, SRP outperforms IIRP with respect to *bp*. Thus, the protocol, SRP can be considered as better performer than IIRP with respect to *bp*.

V. Use of Multiple Wavelengths in MSRP

In MSRP, when a request arrives at a node, the node guesses a wavelength based on the link usage information of the previous link and the *markov_table*. The wavelength thus guessed has the maximum probability of remaining available throughout the route, at that instant of time. Thus when the source initiates a PROB, the PROB moves towards *destination*, and each node after receiving the PROB, performs the following major tasks for the request: (i) detects the wavelengths already guessed by earlier requests and excludes them from *prob_set*, (ii) guesses a wavelength for this request from the remaining free wavelengths and updates PROB, (iii) initiates on-demand splitting (dynamically) if necessary. MSRP adaptively splits a probe attempt into two concurrent (upstream and downstream) reservation attempts at some intermediate node selected dynamically. For a request, if *hop_count* is the number of hops traversed by the PROB, then, splitting may occur provided both the following conditions are satisfied:

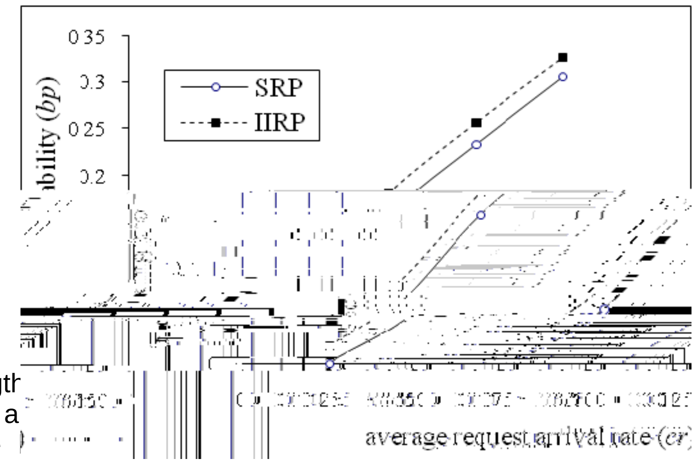

Fig.7: Variation of *bp* with cr for wl=75

(i) (x_1 * d) ≤ hop_count ≤ (x_2 * d) i.e., whether the PROB has traversed more than a pre-selected distance (x_1 * d) of the route as well as less than another preselected distance (x_2 * d), where d is total number of hops of the route, x_1 and x_2 are two positive fractions within 0 and 1, and $x_2 > x_1$.
(ii) the wavelength at *prev_guess_index* is different from λ_{gi}.

If the conditions of splitting are satisfied, splitting occurs; otherwise the PROB propagates to the next node

The variation of x (i.e., x_1 and x_2) is studied in [8]. We select, x_1= 0.5, x_2= 0.6, so that *vulnerable period* as well as *reservation duration* are optimized to have low *bp*.

Two types of broadcasts are used in this protocol: (i) each node broadcasts its adjoining *link usage* information at every T seconds. This *link usage* information is stored at every node. (ii) Broadcast of *link usage* information as mentioned above, is not necessarily correct at an arbitrary time between stored in a table referred as markov_table at all nodes. So essentially markov_table contains the information of rate of change of states of the wavelength usage for all the wavelengths in all the links. T' is considered to be much longer compared to T. If value of T' is lower than a certain level, it is vulnerable to oscillation which may ultimately lead to poor performance.

Since T_{ratio} (the ratio of T' to T) is an important parameter and affects the performance of the protocol, is studied for different set of values of r and wl. It is found that an optimum value of T_{ratio} exists in each case. It is reported that [7],[9] values of T_{ratio} corresponding to minimum value of bp is near 300. Hence, for simulation results, the optimum value of T_{ratio} is kept as 300.

Multi wavelength approach is used on MSRP and the scheme is referred as MMSRP. Since Markov model uses Markov chain to describe each state of wavelength usage, so maximum allowable transition is one. Thus, multiple number

Source sp_2 sp_1 Destination

PROB

PROB

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