Channel assignment schemes for WDM-based Personal Communications Network

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***Abstract*-As the cover range of the radio cells is gradually smaller than before, the procedures for mobile terminal call setup and control become complicated due to the high handoff frequency. The broadcast nature of WDM star couplers makes the handoff scheme easier, and reduce the number of continuous reconnections. In this paper, Based on the WDM-based PCN Architecture, a channel allocation algorithm is used to keep the offset conflict probability as low as possible. Simulation results show that the wavelength-offset assignment scheme performs better than the other schemes in offset conflict probability under moderate roaming rate.**

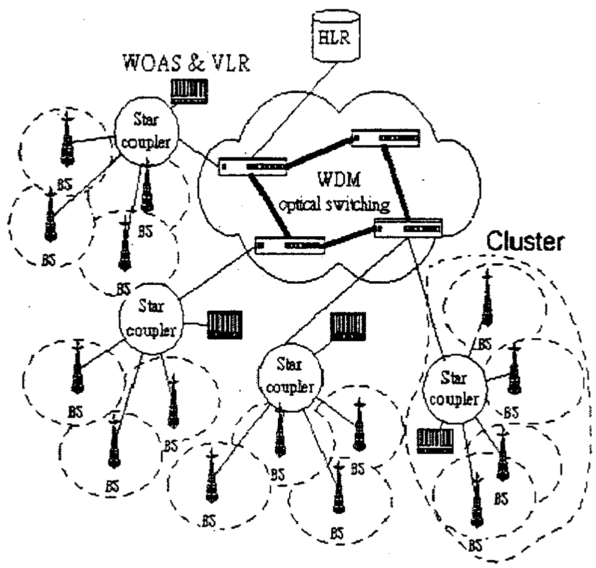

Fig. 1. WDM-based PCN architecture

I. INTRODUCTION

To meet the increasing demand for multimedia processing and communication services, fiber optics transmission technology has been accepted as the realistic solution for the future growth of the communication network. WDM (Wavelength Division Multiplexing) allows the optical bandwidth to be efficiently exploited, and each wavelength channel can reach the speed of gigabit/sec. It is expected that WDM network is the proper backbone for next generation Personal Communication Network (PCN).

In Section 2, the architecture of WDM-based PCN System [1] and the *offset conflict problem* is introduced. Three offset allocation assignment algorithms are proposed to reduce the offset conflict rate as low as possible stated in Section 3. The simulation model and results are reported in Section 4. Section 5 is the conclusion.

II. WDM-BASED PCN SYSTEM

A. *Architecture*

In [1], the WDM-based PCN architecture is based on the single-hop WDM star couplers and WDM optical switching as illustrated in Fig 1. In other architecture of Personal Communications Network, like CATV-Based PCN [2], the whole covered geographical area is a broadcast domain. That is, data for a user are actually broadcast to all the other nodes in the network. Thus, this broadcast nature provides the opportunity to design fast and simple handoff procedures. In the WDM-based PCN, the area must to be partitioned into several disjoint clusters due to the restriction of optical device (star couplers) can only be connected by limited base stations. Each cluster is a broadcast domain connected to a star coupler and every star coupler is connected to a WDM optical switching which is interconnected by point-to-point optical links with others. Each cluster consists of a set of microcells, each of which has a base station within the cell to exchange radio signals with wireless mobile terminals. In order to furnish network configuration, a database called home location register (HLR) storing the user profiles, and a database called visitor location register (VLR) which stores the location information of the mobile terminals are required. We assume a HLR attached to one of the wavelength switching and a VLR attached to each star coupler. We also need a mechanism to assign appropriate wavelength and offset to users in a broadcast domain called Wavelength and Offset Assignment Scheduler (WOAS).

In the WDM-base network, we employ both WDMA and TDMA multiplexing techniques. Each WDM channel corresponds to one specific wavelength and each channel further divided into fixed-length slots, called offset. Thus, a connection can be assigned an offset O_j of a wavelength λ_i by WOAS and presented as (O_j, λ_i).

The lightwave channels are categorized into data channels and a control channel. A specific wavelength is reserved as the control channel for transmitting control messages, the other wavelengths are allocated as data channels for transmitting general data. The control messages contains call setup request, handoff signals, and WOAS wavelength-assignment commands, etc.

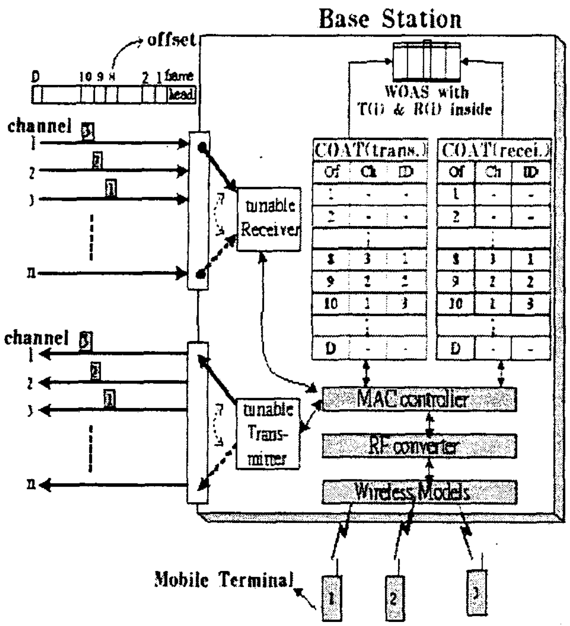

Fig. 2. Architecture of the base station

Due to cost consideration, each base station is equipped with only one tunable transmitter and only one tunable receiver for data transmission, one fixed transmitter and receiver pair for signals control. Besides, the following four modules compose the base station (see Fig.2): the wireless module, Media Access Control (MAC), the Radio Frequency (RF) converter, and channel-offset allocation table (COAT). The wireless module is in charge of communicating with mobile terminals within the cell. The MAC protocol defined by IEEE 802.11[3] can be a protocol of the radio links between the wireless module and mobile terminals. The RF converter is responsible for interchanging the signal format between the wireless RF signals and WDM channel signals. The COAT of each base station keeps the assigned channel and slot (by the WOAS) for each of the serving mobile terminals. Each entry in the COAT is (Ch, Of, ID), which means the offset (Of) of the channel (Ch) is assigned to the mobile terminal whose Identity number is ID. The tunable transmitter or tunable receiver can be tuned to specified channel to transmit or receive data by looking up the COAT. The tunable pairs can be tuned to any wavelength channel, but only one channel at a time. This is an important concept to recognize the offset conflict problem. Owing to the tunable receiver can receive only one channel at a time, the offset of each mobile terminal in a base station should be unique. The offset conflict problem happens when a mobile terminal move into a neighboring cell and the assigned offset (s) identical to that of other exiting terminal in the cell of the neighboring base station. Then, a new offset must be assigned for this mobile in the new base station by more handoff procedures.

B. *Call setup procedure*

In a Personal Communications Network, mobile terminals communicate with the wired network through a base station. So the base station is the interface between wireless and wired WDM network. As mentioned above, a broadcast domain (called cluster) that is composed of several cells is a registration area (RA). In the covered area of RA, all base stations are wired to a star coupler. When a mobile terminal wants to establish a connection to the server in the network, the mobile terminal first sends a connection request and its mobile ID to the base station. The base station first forward the connection request and transmits its channel-offset allocation table (COAT) to the WOAS. For example, a connection is to be established between BS1 and BS2. If BS1 and BS2 are not within the same cluster, any offsets not used at the transmitter of BS1 can be assigned. Otherwise, only the offsets not used at the transmitter of BS1 and receiver of BS2 can be assigned. If the WOAS can not find an available offset of channel that is conflict-free, the connection request will be rejected. Otherwise, the request is granted by the WOAS, and WOAS will reserve bandwidth in the channel for the connection. The channel numbers and the offsets are sent to the base station to update its COAT and furnish the connection setup. The WOAS only reserves the slots whose are different from those assigned in the COAT of the base station in order to prevent the offset conflict.

C. *Handoff procedure*

In a WDM-based PCN, there are two types of handoff process: interior handoff and exterior handoff. Interior handoff happens when a mobile terminal moves from a cell to the neighbor cell within a cluster. If a mobile change registration area (moves from a cluster to the other), it is called exterior handoff. When a mobile terminal powers-up, powers-down, or changes RA, it generates registration messages to the base station in order to identify itself. Each base station periodically broadcasts an identifying message (within the cell) including the base station identifier and the cluster identifier which it is located. Base station identifier is used by mobile terminal to identify which it is located and when to handoff (interior handoff) if the mobile terminal changes cells; and the cluster identifier is used to recognize exterior handoff if the mobile terminal roam outside a cluster. When the exterior handoff occurs, it is viewed as a call setup procedure (due to the mobile terminal move out the broadcast domain and the packets have to be routed through optical switching). The base station transmits the handoff message to the WOAS for updating the database of VLR and transmits the new location information to the HLR. HLR will deregister the mobile terminal at the old RA, if the successful registration is verified by the WOAS.

If a mobile terminal handoff from base station BS1 to base station BS2 within its RA (interior handoff), a seamless and fast handoff can be purveyed due to the broadcast nature of the WDM star coupler. The mobile terminal first sends WOAS a registration message including its ID and the channel-offset assignment of the original base station. WOAS checks the (channel, offset) with the scheduling matrix (define on section 3). If the current assigned offset in BS1 is not occupied in BS2, the mobile terminal will continue using the same (channel, offset) without complicate handoff procedure. Otherwise, if offset conflict occurs, the WOAS will find new offset for the mobile terminal. Then BS1 erases the corresponding entries of its COAT and BS2 adds the channel-offset data into its COAT.

III. WAVELENGTH AND OFFSET ASSIGNMENT ALGORITM

In order to realize a seamless and fast handoff, the offset assignment algorithm must keep the offset conflict probability as low as possible. The WOAS is responsible for the wavelength-offset assignment (reassignment) when a mobile terminal sends a connection request or handoffs to a new base station with offset conflict. The two WDM-based PCN wavelength-offset algorithms proposed in [1] are RANDOM algorithm and Least Used Offset (LUO) by Neighbor algorithm.

The RANDOM algorithm randomly selects the offsets that have not been used. And the idea of the LUO algorithm is that the offset conflict problem happens only when a mobile terminal handoffs to its neighbor cells. So we select the offsets that are not used by all its neighbor cells. Thus, when the mobile terminal moves to any of its neighbor cells, the assigned offset in the cell is free and the offset conflict problem won't happen. The detail of this algorithm is described as follows. The WOAS maintains a pair of transmitter scheduling matrix T(i) and receiver scheduling matrix R(i) for each connected base station BS_i. Each base station tunes its transmitter or receiver to specific wavelength at specific offset (slots) by looking up the scheduling matrix T (i) and R (i).

$$T(i)=\begin{bmatrix} t_{11} & t_{12} & \cdots & t_{1n} \\ t_{21} & t_{22} & & t_{2n} \\ \vdots & & \ddots & \\ t_{m1} & t_{m2} & & t_{mn} \end{bmatrix} \quad \text{and} \quad R(i)=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & & r_{2n} \\ \vdots & & \ddots & \\ r_{m1} & r_{m2} & & r_{mn} \end{bmatrix}$$

Where the number of available wavelengths is **m** and the frame in each wavelength is partitioned into **n** time slots. The value in each entry t_{ij} is **1** or **0**. If $t_{ij}=1$, the transmitter should tune to wavelength λ_i at time slot O_j to transmit packets for the connection. Otherwise, the time slot O_j is free in the transmitter. Similarly, the receiver's matrix entry with $t_{ij}=1$ (0) is the same meaning as t_{ij}. When a mobile sends a call setup message to the base station or the base station detects an offset conflict, the base station transmits the scheduling matrix to the WOAS. Then WOAS requests the entire cells adjoining the base station to send back their scheduling matrix then selects the *Lth* offset which least used in neighbor cells. The LUO algorithm performs better than RANDOM algorithm since the information of neighbor cell are taken into account. The disadvantage of this algorithm is the high time complexity since more channel allocation data have to be calculated.

In our WDM-based PCN architecture, a more effective offset allocation algorithm without dealing with the extra information of the neighbor cells is adopted for WDM structures first time. It is called Preempted Assigned Offset (PAO) algorithm.

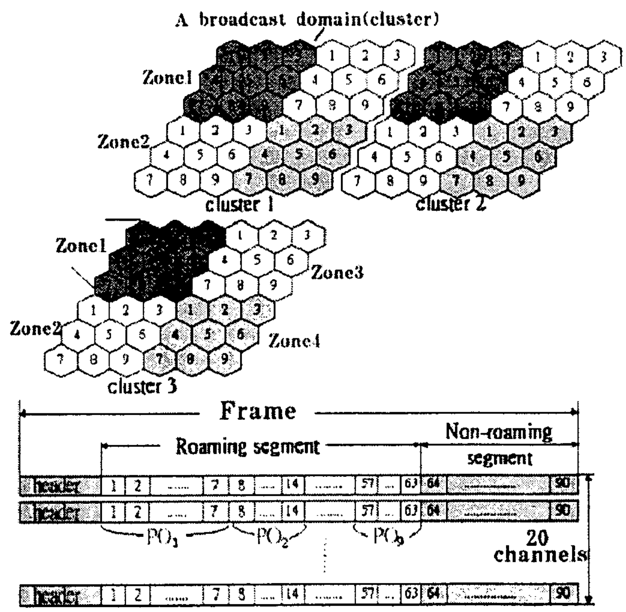

Fig. 3. The concept for PAO algorithm

In the PAO algorithm, the entire offsets are divided into two segments: the roaming segment and the non-roaming segment. The offset of the roaming segment are intended to be assigned for roaming mobile terminals, where the non-roaming segment are assigned for non-roaming mobile terminals. When a mobile successful furnish a call setup procedure, it is regarded as a non-roaming mobile by its base station. This mobile will first be assigned the unused offsets of the non-roaming segment randomly. If all the offsets in the non-roaming are occupied, the unused offsets in the roaming segment are selected (as a roaming mobile). But when the mobile terminal handoffs to a neighbor base station, it becomes a roaming mobile.