Journal of Computer Sciences 1 (2): 145-150, 2005
ISSN 1549-3636


# Formation of Optimal Messages Path Delivery Within a Virtual Channel Technology

[1]Al-Bdour, H. and [2]Kaabneh, K.
[1]Mutah University, Jordan, [2]Amman Arab University, Jordan

**Abstract:** This research study deals with the process of reduction and optimization of data transmission delays in mobile Internet networks during mobile subscriber transmission (SsS) to various coverage areas. The methods for information transmission in IP-networks and networks based on virtual channel technology are investigated. Throughout this research, special attention is given to the analysis of existing methods for channel reconfiguration within the framework of virtual channel technology. The modified rerouting plan is presented and proven for its effectiveness and efficiency.

**Key words:** Channel Reconfiguration, IP-networks, Mobile Internet Networks, Virtual Channel Technology

## INTRODUCTION

The topicality of this research is stipulated by the fact that a modern network technology, such as Internet, combined with wireless data links, allows access to various network service types at any time. In turn, specific features of mobile wireless network organization necessitate the search for new routing methods. The majorities of known routing algorithms are focused on finding the shortest path and disregard migration of subscriber systems [1-3]. For instance, finding the common optimal path for all base stations, which may serve mobile node, allows the reduction of rerouting time, which in turn facilitates higher efficiency of the entire network operation. Within the framework of this research, this problem is presented and solved by using a new optimal path-building algorithm for delivery of messages to mobile subscriber system (SsS).

The problem with optimal routing is that routing algorithms are required in order to select a set of optimal paths for any given measure. For mobile computer networks, a delivery route optimality criterion would be the minimal rerouting time and providing uninterrupted information transmission at subscriber systems movement; in this case, the path length defined by a category of constraints. The rerouting time depends on the number and time of returns while on the route as a result of subscriber systems movement [4, 5].

The rerouting time $T_i$ in mobile Internet networks between two adjacent routers can be defined in the following formula:

$$T_i = T_c + T_m \tag{1}$$

where $T_c$ and $_m$ can be defined as the time of transmission via the communication line between two nodes and the time of IP header processing and packet routing.

If we use the existing optimized routing algorithm for IP networks, then path reconfiguration between the sender and mobile SsS will be [6]:

$$T_i = \sum_{i=1}^{k} (T_{c_i} + T_{m_i}) \tag{2}$$

Where $k$ is the number of intermediate nodes.

In networks based on virtual channel technology, the rerouting time $_{vc}$ between two adjacent leaves in the tree is:

$$T_{vc} = T_c + T_k \tag{3}$$

where $T_c$ is the time of transmission via tree segment between two nodes and $_k$ is the time of channel switching, at which $T_k << T_m$

If routing is reconfigured using *full path reinstallation* method and then given the same number ($k$) of intermediate nodes, the rerouting time will be much shorter in comparison with IP networks. This is related with short channels switching time [7].

$$T_{vc} = \sum_{i=1}^{k} (T_{c\,i} + T_{k_i}) \tag{4}$$

The *path extension* algorithm guarantees rapid reconfiguration, but may result in an inefficient routing procedure [8]. In particular, there are cycles when a mobile SsS moves closer only to the nearest cells. Even if the switched path to the necessary node exists, the new path is nevertheless created. Then:

$$T_{vc} = \sum_{i=1}^{x} (T_{c\,i} + T_{k_i}) \tag{5}$$

where $(x)$ is the number of intermediate nodes.
By using *preventive path installation*, then by the time of the information transmission we should build a tree for delivery to all possible locations of mobile SsS movement [9]. The tree node where the route is changed is called "route branching point". Given some number $k$ of intermediate segments consisting of $j$ branching points, the routing time is equal to:

$$T_{vc} = \sum_{i=1}^{k} T_{ci} + \sum_{z=1}^{j} T_{pj} \qquad (6)$$

where is the switching time at the branching point and $j <= k$.
During consecutive visitation of all leaves for creation of such tree, each branching point is visited *m-1* times, where: *m* is the number of descending branches in the tree.
As a result of the above analysis, we conclude that in networks based on virtual channel operation, the use of preventive installation methods archives rerouting time reduction by lowering the number of levels (intermediate nodes) in the tree. Therefore, the problem of rerouting time reduction may be simplified to path building problem, for which the average rerouting time for all probable connection points is minimal.
Virtual Channel Provisioning
Given the fact that the router spends significant time processing each packet in addition to complex processing of the traffic, intellectual algorithms of filtration and route selection given several possible paths [10]. The process of routing may be accelerated due to revealing steady flows in the network and the processing of only several first packets in the flow based on the routing plan.
The flow is a sequence of packets sharing some properties; for example, they have the same address of the sender and the receiver. Only then can they be sent via the same route. In order to maintain high probability that the sequence belongs to the same one and the same flow, we have used an additional identification parameter called the *Flow identifier* as described in the IPv6 protocol shown in Fig. 1).

| Version (4) | Prior (4) | *Flow identifier (24)* |
|---|---|---|
| | | … |

Fig. 1: IPv6 Header Fragment

Using the virtual channel technology, each allocated flow shall be placed in the new virtual channel. When passing the first packet of the flow, the router should create a record on the generated channel based on the routing table. When receiving the other datagrams of the given flow, the router then will access the switching table, which reduces the time of processing and transmission of packets as switching occurs at the channel level.
In order to organize the virtual channels operation, a switching table is added the to the router as shown in Fig. 2, where *In port*, is the number of the port via which the packet gets in the router, *In VC*, is the input virtual channel identifier, *Out port* is the number of the port to which the received packet shall be transmitted, *Out VC* is the output virtual channel identifier assigned to the packet being sent and finally, *Flow label* is the identifier of the flow, which determines that a packet belongs to a given flow.

| *In port* | *In VC* (8 bits) | *Out port* | *Out VC* (8 bits) | *Flow label* (16 bits) |
|---|---|---|---|---|

Fig. 2: Switching Table

The above organization of virtual connections provides bi-directional channels operation, i.e. the names Input and Output are arbitrary. In fact, they specify which ports should be switched to transmit the packets in the given flow to the next node.
The organization of the virtual channels requires determining which field in an IP packet will show the numbers of input and output virtual channels, as these identifiers are unique only for the given router. Knowingly, marking of virtual channels uses 8 bits [11]. Such marker may be a part of *Flow Label* field in IP header of the packet. In this case, the router masks this field to retrieve the virtual channel number.
Once the sender has retrieved the current address of mobile SsS, then the sender should be sent an information packet to establish the virtual channel connection. For this purpose, it writes down the updated address of the mobile node in the IP header of the packet, while the identifier of the flow to be transmitted gets written in the FL field. After that, the sender selects the unused virtual channel number and sends the packet to the next node as shown in Fig. 3.

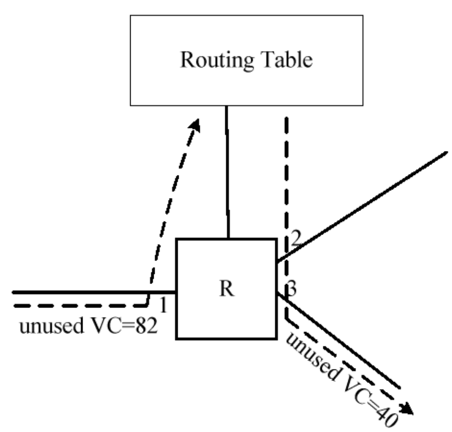
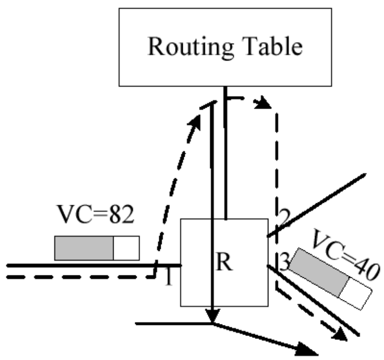



Fig. 3: Virtual Channel Connection

When receiving the packet, the router according to the basis of routing tables selects the source port and unused number of the virtual channel after which the datagram is sent with the newly assigned VC. A new binding record is then written to the switching table (input port, input VC)→(output port, output VC) is created.
The subsequent packets of the flow will have the home address of the target written in their headers as the virtual channel has already been established.
When the subsequent packets of the flow get to the router, it uses masking to retrieve VC number and forwards the packet using the routing table as described in Fig. 4.




VC Table

| In port | In VC | Out Port | Out VC | FL |
|---|---|---|---|---|
| 1 | 82 | 3 | 40 | xxx |

Fig. 4: Routing using Routing Table

**Rerouting:** Building the route is a measure done based on the fact that SsS may move. Generally, the network is a set of mobile SsS and stationary switching nodes. Between the fixed nodes of the network, a route, as a rule, is a path ($P_{i,j}$) from vertex $v_i$ to vertex $v_j$ of the graph representing the network topology.

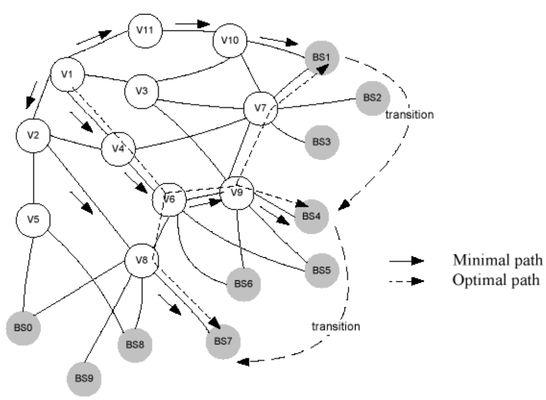



Fig. 5: Mobile Network Structure

In reference to Fig. 5, several paths exist between vertices $v_1$ and $v_8$, (where: $v_i$ is a fixed node of the network) one of which is path $P_{1,8} = (v_1 - v_4 - v_6 - v_8)$. If an SsS moves, the path is changed. For instance, if an SsS moves beyond the coverage area of the base station ($BS_1$) to the coverage area of $BS_7$, the initial path $P_{1,10} = (v_1 - v_3 - v_{10})$ may change to path $P_{1,8} = (v_1 - v_2 - v_8)$. Known routing algorithms build the shortest path tree between the source and all targets. Assuming there is the shortest path $P_{1,9} = (v_1 - v_3 - v_9\ BS_4)$ between vertices $v_1$ and $BS_4$. In this case movement of the subscriber system from $BS_4$ to $BS_7$ requires that the route be changed completely. However, we would get to $BS_4$ by selecting another path $P_{1,9} = (v_1 - v_4 - v_6 - v_9 - BS_4)$. In that case, route change will be minimal at transition to $BS_7$, as the core segment of the route ($v_1 - v_4 - v_6$) does not change. In order to streamline the path change procedure in the graph in case of SsS movement from one cluster to another, it is expedient to use the common paths with the minimal number of intermediate vertices.
In the majority of known routing algorithms, the optimization criterion is the delay in information transmission, or information delivery time [12]. Naturally, the minimal delivery time in this case may be much less than allowable. In addition, the time of the subsequent rerouting may be overestimated. An example of such delivery tree is indicated with arrows in Fig. 5.
The optimal delivery tree from the rerouting time minimization point of view is indicated in Fig. 5 using the dashed line. In this case, SsS movement from the coverage area of one BS to the coverage area of another BS does not change the core segment of the route. In this case, movement of the SsS from the coverage area of $BS_1$ to the coverage area of another BS, located inside the same cluster does not change the path $P_{1,5} = (v_1 - v_2 - v_3 - v_5)$. Even if the SsS moves to another cluster, only a segment of the initial path changes from ($v_3$-$v_5$) to ($v_3$-$v_4$).
Let us assume that the common path ($S_i$) in the tree with root vertex $v_2$ includes all vertices except dangling vertices. In this case, dangling vertices include the initial vertex $v_1$ and all vertices corresponding to the base stations. Therefore, for vertex $v_1$ the common path in $BS_0$ - $BS_3$ shall be deemed path $S_1 = \{(v_2), (v_3), (v_5)\}$ and in $BS_4$ - $BS_6$ it will be path $S_1 = \{(v_2), (v_3), (v_4)\}$. The vertices in parentheses belong to the same level of the tree; at the same time, the uppermost level includes the vertices located to the left.
The sources of information may be all terminal nodes and SsS nodes. In this case, we should build some optimal common path for $BS_j$, where $j$ is the number of targets. Building the common path, for new root vertex $v_i$ ($v_1 \notin V_S$) we are finding the minimal path $_{i,s}$ from the root vertex $v_i$ to the nearest vertex $v_j (v_j \in S_1)$ provided that the time of delay in information transmission via the path $P_i$ does not exceed the allowable value, i.e. $T_{si} \leq T_{max}$.

**Suggested Algorithm Description:** While moving, subscribers change their physical locations in the network topology. This also changes the delivery route, i.e. there is a transition from one branch of the delivery tree to another. In view of the below suggestions on optimization, the developed algorithm builds the initial path so that movement of the subscriber creates only minimal changes to the delivery route.

The suggested algorithm is built upon the principle of virtual channels operation for fast rerouting in case of BS changes by the mobile node. Based on this principle, the rerouting method is suggested, which, at installation of connection, finds the optimal common path for a set of BS nodes (possible areas to handoff candidates), based on the type of mobile node movement. Such approach essentially reduces the rerouting time owing to fast virtual channel reconfiguration.

The algorithm finds the common path for all probable BS nodes so that movement of a subscriber from one vertex (BS) to another minimizes the difficulty of route change, i.e. the mobile node transition paths from one coverage area to another is made with the minimal paths from the old (disconnected) and the new (active) BS, to the common segment of the route. Therefore, the number of intermediate nodes during the new route building is minimized. If a subscriber moves in the network, the type of movement is known. Hence, the next location of the mobile node in the network is determined by probabilities (Ps). In that case, to solve the problem finding the common path, we suggest using the following common criterion of minimization

$$Z_p = \sum_{n=1}^{k} (Ps_n) \qquad (7)$$

Where p is the router port number, $k$ is the number of minimal paths from the given router to BS which pass through the $p_{th}$ port and $Ps_n$ is the probability that given BS nodes will serve the mobile node.

This criterion calculates the probable direction of the required path. If there are several minimal paths for BS nodes that pass through different ports, all possible minimal routes shall be taken into account. If several minimal routes pass through one port, the criterion takes into account only one path.

As the optimal path is built based on the location of the active base station and type of mobile node movement, the current BS shall be given the highest priority. This is related to the fact that at that moment the data should be transmitted to this node. In that case, we should assign Ps=1 to the active base.

The idea of building such common path consists of the following. First, using the Dijkstra algorithm we find minimal paths from the source vertex to all BS nodes that may serve the mobile SsS. For each port, other than The port that received this packet, the factor

$$Z_p = \sum_{n=1}^{k} (Ps_n)$$

of the required path passage via such port is calculated. The router determines the port for which $Z_p$ is maximal (at the same time it should be equal to or greater than 1) and checks the accessibility of the whole BS node set. If all specified BS nodes are accessible and the distance to the BS less than the allowable Dmax then for the given flow the new virtual channel in the specified port is allocated and then a transition to the next router and calculation of factors is performed. Otherwise, the port with lower $Z_p$ is selected and we check the accessibility of all BS nodes through it. If we enumerate all ports through which the active base is accessible and find out that there is no such output where all vertices are achievable, then this router is the final point of the common path for all coverage areas. In this case we should select the port where $Z_p$ reaches maximum and those vertices that are not accessible shall be removed from the list. We should then find the common path for the BSp which remains on the list. The criteria of the developed algorithm completion are that the packet reached the target or the BSp list contains only the active coverage area. In the second case, we should continue searching for the path by using Dijkstra algorithm.

The algorithm of virtual channel provisioning consists of the following: First, the router masks the FL field in the IP header of the packet in order to determine the input VC identifier. Then, based on the switching table, it selects the unused virtual channel identifier (unused VC ID) using the target port. The virtual channel number selected is written in the FL field of the packet; then the packet is transmitted to the next router and the new binding record (input port, input VC)→ (output port, output VC) is added to the switching table.

When the mobile host passes to a new BS service area, it sends the old agent its current address by using *Binding Update*. Then, the rerouting procedure is performed.

Via the established virtual path, the packet moves "upwards" (in the opposite direction) up to the branching point. Then, using the normal plan a new record is added to the switching table, where the source fields contain the port and virtual channel number through which the packet was received from the old BS. Then the packet is transmitted and the record in the table is updated. The change in the table is required because the data getting in the router shall be routed to the active, rather than passive BS.

Then, using the table, we check the record where FL field matched the same field in the newly added record. In such record, we rewrite the output port and virtual channel identifier. As a result, this router for this flow contains two records that characterize the following directions:

Old BS-> active BS,
Sender-> active BS.

The first shows in what direction we should transmit the data received from the old BS after the mobile node disconnection from it.
The second record shows which ports should be switched in order to transmit the data to the new BS.
The subsequent nodes search for the optimal path using the algorithm described above, when they receive the setup packet.
Once the virtual channel is established for the given flow, intermediate routers do not lookup the routing table any more and transmit the packets based on the VC table.
Assume that transmission of the data flow passes in the following direction (Fig. 6). In that case, the virtual channels table contains the relevant switching record. When a mobile node changes the base station (Fig. 7) we should change the transmission route.
In the process of rerouting, when we should set the new path, each node will send the packet using the old route and then using the "common" for all coverage areas route to the so-called branching node (Fig. 8). In the branching node, based on the routing tables, the optimal path to the new coverage area in the same path is calculated in the same way as for the common path search. Then, a new virtual channel record, where the sender is the old base station, is added to the switching table. Therefore, the route to the new BS is organized, through which the information buffered in the old base station will be transmitted.

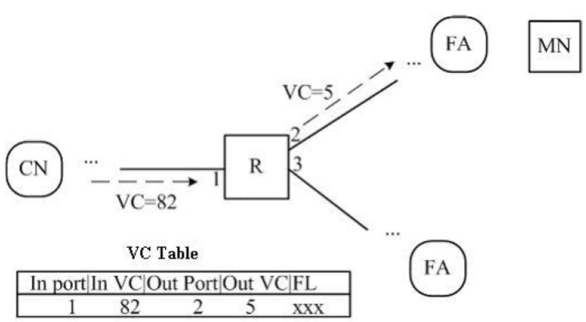



Fig. 6: Data Flow Direction

In order for the flow sender to transmit information directly to the new coverage area without transmission of the service information, we should update the relevant record in VC Table. In this table, the router looks up the identifier of the flow which route shall reconfigure in FL field and copies the values of the port reference number and the virtual channel ID.

**Algorithm Operation Simulation:** For our investigation, we built a network model (Fig. 8).

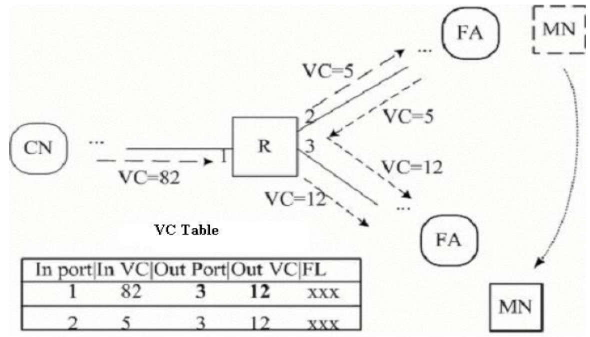



Fig. 7: Mobile Node Changes the Base Station

**Legend:** Vertex No. 1- source vertex. White vertices are routers connected with the communication channels and forming the fixed network infrastructure.
Grey vertices are terminal nodes of the network (BS).
The metrics submitted reflect the cost parameters of the communication channels.

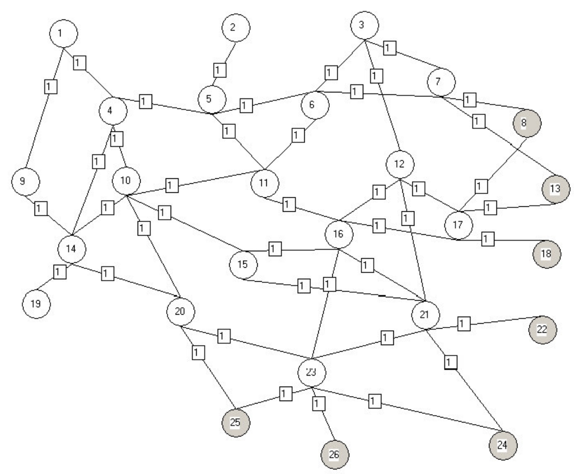


Fig. 8: A Network Model

The optimized routing algorithm detected the following paths in IPv6 networks: $S_{1,8}=(P_1\text{-}P_4\text{-}P_5\text{-}P_6\text{-}P_7\text{-}P_8)$, $S_{1,22}=(P_1\text{-}P_4\text{-}P_{10}\text{-}P_{15}\text{-}P_{21}\text{-}P_{22})$, $S_{1,26}=(P_1\text{-}P_4\text{-}P_{14}\text{-}P_{20}\text{-}P_{23}\text{-}P_{26})$ that resulted in the common path $S_{cmn}=(P_1\text{-}P_4\text{-}P_{10}\text{-}P_{15}\text{-}P_{16})$.
In the process of simulation we assume investigating the path reconfiguration time, resulting from the movement of the subscriber from the coverage area of the old BS, to the cover area of the new BS. We would be interested in the rerouting time as a function of the number of intermediate nodes provided that the common path from the sender to the mobile node equals to the given value. Let us simulate the network topology with various ratios between the common path and the whole packet route. The simulation results (Fig. 9) have shown the following overall efficiency of the method in comparison with the standard.
The simulation results are given for cases when the

common path is 10, 30, 50, 70 and 90%. Long time leaps show that paths pass through the inter-network routers.

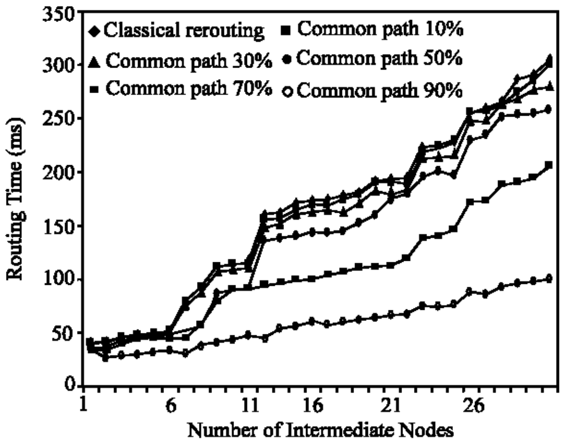


Fig. 9: The Simulation Results

## CONCLUSION

The analysis of the simulation results confirms the efficiency of the suggested algorithm and shows the reduction of the rerouting time on the average by 10%-20% in comparison with the baseline. The algorithm is especially efficient for networks with high-level hierarchies where a gain of exceeding 20% is achieved. Based on the graphs, a conclusion can be made that the efficiency of preventive algorithm expands with the increase in the common path length in the route.

In the event that the common path is a small part of the route, the algorithm shows nearly the same results as the routing algorithm for Internet networks. This is explained by the fact that the suggested algorithm is based on the principle of Dijkstra algorithm for shortest path selection.

As seen in the graphs reflecting the simulation results, the algorithm shows the optimal results for networks with high-level hierarchies i.e. for networks with high degree of complexity and many intermediate nodes.

The suggested algorithm performs rerouting based on the virtual channels plans creating the common path from one subscriber connection to all possible areas to the handoff-candidates and fast rerouting. While the algorithm reduces the packet transmission delay during changes in the coverage areas by the mobile subscriber, this may influence much higher costs of handoff, which never happens.

## REFERENCES

1. Deering, S. and R. Hinden, 1998. Internet Protocol. Version 6 (IPv6) Specification, IETF RFC 2460.
2. Atkinson, R., 1995. IP Authentication Header, RFC 1826.
3. The ABCs of IP Version 6, 2002. Cisco IOS Learning Services, Inc.
4. Peterson, L.P. and B.S. Davie, 2000. Computer Networks. A Systems Approach. 2nd Edn. pp: 328-340. Morgan Kaufman.
5. Tuomas Aura, 2002. Internet mobility. Microsoft Research.
6. Bhagwat, P., C. Perkins and S. Tripathi, 1996. Network layer mobility: An architecture and survey. IEEE Pers. Commun., 3: 54-64.
7. Valko, A.G., 1999. Cellular IP: A New Approach to Internet Host Mobility. ACM Comp. Commun. Rev.
8. Johnson, D. and C. Perkins, 2000. Mobility support in IPv6. IETF Internet Draft.
9. Basavaraj Patil, 2003. IP mobility ensures seamless roaming. Communications Design.
10. Campbell, A., J. Comez and S. Kim, 2002. Design, implementation and evaluation of cellular IP. IEEE Personal Communications, pp: 42-49.
11. Charles E. Perkins, 2002. Mobile IPv6 Update. Nokia IPv6 Workshop.
12. Lockwood, J.W., 1999. Implementation of campus-wide wireless network services using ATM. Virtual LANs and Wireless Basestations, Wireless Communications and Networking Conf. (WCNC'99), New Orleans, LA.