(MV) receiver. From this, we know that the little sacrifice of the transmitting power gives high performance enhancement. Also, it shows better convergence property than others due to the modified canonical representation in the severe near–far scenario. Fig. 2 shows the convergence behaviour of g. It shows that the convergence rate of g is also fast.

Conclusion: We propose a novel linear MMSE receiver using a hidden training sequence and its adaptation algorithm based on the modified canonical representation. From the simulation results, we verified that the proposed receiver shows good performance.

 24 January 2003
Electronics Letters Online No: 20030482
DOI: 10.1049/el:20030482

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Routing algorithm for specialised long-lifetime pico-radio networks

Y. Wang and T. Arslan

A novel routing algorithm which distributes the power consumption rate of each node evenly in a class of specialised mobile ad hoc networks, termed pico-networks, is presented. The algorithm adds one additional factor to the cost metric of paths in order to prevent the overuse of specific piconodes. Simulation results show that the new routing algorithm can prolong the lifetime and significantly improve the quality of a pico-radio network.

Introduction: Technology advances have made it possible to deploy ad hoc and flexible networks with some small, lightweight, low-cost network elements (often termed piconodes). These nodes are generally associated with restricted constraints such as: occupying smaller than one cubic centimetre, weighing less than 100 grams, and having ultra-low power consumption and low cost [1]. Trying to network a large number of such power-constrained piconodes is a challenging problem that has recently been the focus of many researchers. As a result, a number of routing schemes [2,3] have emerged that utilise the limited resources available within piconodes more efficiently [4].

In this Letter we present a novel routing algorithm for long-lifetime pico-radio networks. Most schemes in the literature typically try to identify the minimum energy path to optimise the energy usage of a node. However, the lowest energy route may not be the optimal path from the point of view of network lifetime and quality. Our algorithm builds on the conventional Bellman-Ford algorithm by incorporating a factor due to the cost metric of a given path. This cost metric is adapted by tracking the number of times each node on the route has previously established a network path successfully.

Algorithm: Currently most routing schemes are based on the Bellman-Ford shortest path algorithm, in this algorithm every piconode has to maintain a distance table which stores the distances and shortest paths for sending packets to each of the other nodes in the network. The information in the distance table is always updated by exchanging information with the neighbouring nodes. The starting assumption for most routing algorithms is that each node knows the cost of the link for each of its directly connected neighbours.

The potential problem in current routing schemes is that these find the lowest energy route and then use this for every communication. However, this is not the most effective approach when network lifetime is considered. Using a low energy path frequently leads to energy depletion in the nodes along that path and in the worst case may lead to network partitioning [4].

To solve this problem, we propose a novel routing algorithm that we call *adaptive routing algorithm*. The basic idea is to increase the cost metric of paths which go through nodes used to establish routes previously. This ensures that the network degrades gracefully as a whole rather than getting partitioned. In the conventional Bellman-Ford shortest path algorithm, the cost metric of each route is fixed. This research aims to add another dimension, 'adaptation' to the routing algorithm of pico-radio networks.

Our adaptive routing algorithm could prevent a specific piconode being overused. In the conventional routing algorithm, the most optimal route is selected by comparing the cost metric of all available routes directly. In the adaptive routing algorithm, the cost metric of the path is adapted depending on the frequency of the node used. The metric will be increased by a factor decided by the frequency of the nodes on a given route being used to establish routes previously, e.g. given that nodes N_i and N_j are neighbour nodes, and N_d being a destination node In the conventional algorithm, the cost metric from destination node to N_j is calculated by (1), whereas, with the adaptive routing algorithm, the cost metric is calculated by (2):

$$Cn_j, n_d = \text{Cost}(N_i) + \text{Metric}(N_j, N_i) \tag{1}$$

$$Cn_j, n_d = \text{Cost}(N_i) + (I + n\beta)\text{Metric}(N_j, N_i) \tag{2}$$

Here, metric (N_j, N_i) is the cost metric between N_i and N_j, cost (N_i) is the cost metric of the most optimal route between N_i and the destination node, n is the total numbers of times both node i and node j are used previously to establish other routes, β is the adaptation factor and is a number between 0 and 0.5.

Fig. 1 shows an example of a pico-radio network. Node s is the source node, node d is the destination node. The number of times the specific nodes in the Figure have been used to establish a previous path(s) are as follows: node i (1), node j (2), node a (3), node b (0), node c (1). In addition, assume that the route between node i and node d is being processed by the algorithm as the current optimal path and that cost (i) is the cost metric associated with this path. Using the conventional algorithm, the selection of the next node will be determined by comparison among metric (N_j, N_i), metric (N_a, N_i), metric (N_b, N_i), metric (N_c, N_i). By employing our adaptive algorithm, the comparisons will remain the same, however the cost metric will be adapted by the number of times the node is used to establish other routes. The selection of the next node for the optimal route is determined by the following new cost metrics: $(1 + 3\beta)$ metric (N_j, N_i), $(1 + 4\beta)$ metric (N_a, N_i), $(1 + \beta)$ metric (N_b, N_i) and $(1 + 2\beta)$ metric (N_c, N_i).

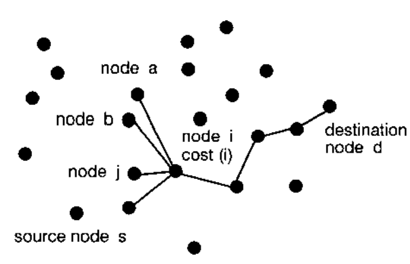

Fig. 1 *Example of piconodes network*

From (2), the adaptation factor is used to calculate the cost metric between one node and the destination node. The metric will increase by an amount depending on the frequency of the nodes being used. The algorithm will continue to compare the amended cost metric among all available routes. The final selected route may not be the shortest route because the cost metric of the original shortest route will increase depending on whether the nodes on this route have been used to establish other routes previously.

Analysis: Our adaptive routing algorithm was simulated using Matlab. During the simulations, we assumed a random cost metric distribution between the nodes. In addition, our simulations are based upon a pico-radio network composed of 100 piconodes with 1000 routes. We assumed that a single route will be established every one minute. Our experiments demonstrated that the best value of β is found to be 0.2. Fig. 2 shows a comparison between the conventional and our adaptive algorithm in terms of the utilisation of each node in the network after the establishment of the 1000 routes. It could be deduced that, using the conventional algorithm, some nodes are used significantly more than others. However, the usage of piconodes with our adaptive routing algorithm is distributed evenly, e.g. using the conventional algorithm one node (node 43) is used 122 times whereas another (node 45) is used only 12 times. However, the number of times any node is used with our adaptive algorithm ranges from 28 to 43, e.g. assuming that any node could be used 50 times at the most, then eight of the nodes will die using the conventional algorithm, but none of the nodes will die using our adaptive algorithm.

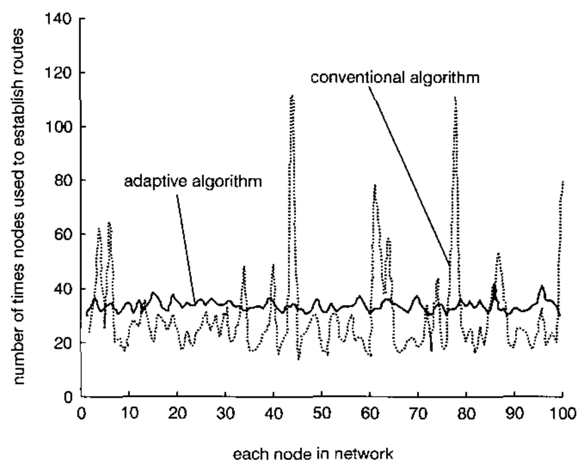

Fig. 2 *Comparison of node utilisation*

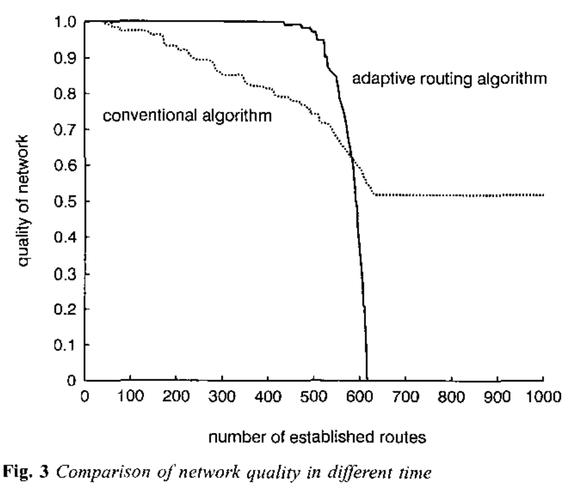

Fig. 3 *Comparison of network quality in different time*

Fig. 3 shows a comparison of network quality between the conventional and adaptive algorithm. Here we assume a node will die after being used 20 times. We define network quality as the number of active/live nodes divided by the total number of nodes. Hence, the network quality shortly after network establishment is equal to 1.

It is clear from Fig. 3 that even after 300 routes have been established using our algorithm the quality is maintained in the network. However, the quality of the network using the conventional algorithm deteriorates to 0.86 rapidly, i.e. 140 nodes have been lost. After 534 minutes (routes), the quality of the network using our adaptive routing algorithm begins to fall sharply. Using our algorithm, a network degrades gracefully as a whole, rather than getting partitioned.

Conclusions: A novel adaptive routing algorithm for pico-radio mobile ad hoc networks has been presented. The algorithm adds one additional factor that makes the routing cost metric adaptive to the number of times nodes on a given route have been used previously. Our results demonstrate that the new adaptive algorithm could prevent nodes from being unwisely overused by evenly distributing power consumption throughout the network. This will in turn extend the lifetime of a pico-radio network and significantly increase its quality.

31 January 2003
Electronics Letters Online No: 20030481
DOI: 10.1049/el:20030481

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User positioning technique for microcellular wireless networks

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A novel algorithm that makes use of a single base station to locate mobile terminals in cellular networks, by resorting to a triangulation technique supported by minimal information about the environment in the base station neighbourhood, is presented. The algorithm is shown to perform well when operating in a microcellular environment and perfect channel estimation is assumed.

Introduction: Radio location techniques open the door to efficient emergency services (E-911) [1], as well as to a new world of both information services (e.g. electronic yellow pages, '*where am I*' applications, navigation and personalised traffic) and location aware radio resource management (RRM) algorithms. Essentially, a radio location system can operate by measuring and processing physical quantities related to radio signals travelling between a mobile terminal (MT) and a set of fixed base stations (BSs). A broad spectrum of algorithms for both modified and unmodified handset solutions can be found in the open literature [2]. In particular, to reduce the implementation complexity and the signalling overhead, significant research efforts are focused on developing solutions using a single BS and unmodified MTs, e.g. the algorithm proposed in [3] utilises information about the scatterers surrounding the BS. The position of the MT is then estimated using the Doppler frequency shift related to each impinging path, thus requiring a moving MT. Another technique, called fingerprinting, locates the MT by matching the radio frequency pattern of the incoming signal to a similar pattern stored in a central database available at the BS.

This Letter describes a new technique using a single BS to locate unmodified MTs, by utilising a triangulation procedure supported by only minimal information about the clutter in the BS neighbourhood. The method requires the characteristics of the impinging multipaths in terms of their propagation delay (referred to as ToA) and angle of arrival