A Simplified Node Selection Algorithm for Multicast Resource Reservation in TDMA-based Narrowband Mobile Ad-hoc Networks

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***Abstract*—The probability of packet collisions, particularly in multicast communications, can be minimised by utilising auxiliary nodes that forward reservation information to hidden nodes. In this paper, a simplified algorithm for auxiliary node selection based on geographical information is proposed and compared with algorithm used in a new NATO draft standard for narrowband MANETs. Since the proposed approach requires only information about single-hop neighbours (which is expected to be both more accurate and more frequently available), the algorithm may be beneficial in situations of high mobility and for initial network entry where only limited neighbour information is available. Utilising single-hop topology information reduces by at least 50 percent both the signalling overhead for reservation and the time until the algorithm achieves correct operation (equilibrium) compared to the NATO reference system. In addition, due to the low complexity, the algorithm may be favourable especially for devices where battery capacity is critical.**

Keywords*—Wireless communication, mobile ad-hoc networks, narrowband, multicast algorithms.

I. Introduction

One of the most remarkable characteristic of mobile ad-hoc networks (MANETs) is the opportunity to establish wireless networks without any fixed infrastructure. Thus, MANETs are a key technology whenever rapid establishment of a temporary communication infrastructure is required. In the field of mobile tactical networks (hereinafter referred to as MTN), used by emergency services such as the police, fire brigades, etc as well as for military applications, future systems will increasingly rely on MANET technology.

A review of operational scenarios for MTNs suggest particular requirements and restrictions for such communication systems [1]. Probably the most important and also challenging requirement is the provision of reliable, long range communication links, i.e. a large coverage, for a predominant portion of multicast voice and/or other real-time traffic as well as quality of service (QoS). To meet the requirement for coverage maximisation, MTNs are mostly operated in the very high frequency (VHF) or lower ultra high frequency (UHF) band [2]–[4], due to more favourable propagation there. Moreover, MTNs mostly operate as narrowband systems with bandwidths of approximately 25 kHz [1] and coverages of up to 20 km and more. In contrast, systems such as IEEE 802.11 (Wireless LAN) operate on substantially higher radio frequencies and with bandwidths of up to some tens of Megahertz commonly providing high data rates of several Mbit/s. However, the coverage of these systems is extremely limited [2] (e.g. some hundred meters). Due to the narrowband nature of MTNs, requirements for QoS are even more challenging than in wideband systems, with particular importance to allocate radio resources both rapidly and reliably enabling multicast transmissions with small delays. Here, the challenge is to minimise the probability of collisions caused by interference due to simultaneous channel access. Although the introduction of IEEE 802.11e addresses the difficulty of QoS in a system based on carrier sense multiple access with collision avoidance (CSMA/CA), systems employing time division multiple access (TDMA) are generally more suitable to guarantee QoS [5].

The North Atlantic Treaty Organization (NATO) has been working on the standardisation of a TDMA-based system (also referred to as *waveform*), named *NATO Narrowband Waveform* (NBWF), for a number of years. One major challenge of this waveform is to enable effective multicast communications in both distributed and self-organising mobile ad-hoc networks (MANETs) while providing avoidance of collisions caused by interference from hidden nodes. The objective here is to optimise the trade-off between minimising the probability of packet collisions and the required signalling overhead to inform hidden nodes about resource reservations. One approach to minimise packet collisions is to use auxiliary nodes that forward reservation information to hidden nodes. NBWF enables resource reservation for both unicast and multicast transmissions by applying a mechanism similar to request to send/clear to send (RTS/CTS) to address both the hidden node and the exposed node problem as well as the neighbourhood capture effect. A typical issue in this context and particularly for multicast scenarios is the selection of auxiliary nodes which, if necessary, respond to signalling messages such as resource reservation requests, etc.

The subject of this paper is first an evaluation of the selection algorithm of auxiliary nodes, which are involved in the reservation process for multicast transmissions, from a single-hop neighbour set proposed for NBWF. Secondly, a new, simplified algorithm based on geographical information is introduced and compared to the NBWF algorithm. In situations where perfect knowledge of the network topology is not available, the simplified selection algorithm shows comparable performance. As the proposed approach requires only single-hop information, which is expected to be both more accurate and also more frequently available, the simplified algorithm shows more favourable performance in cases of high mobility and at initial network entry when nodes have only limited neighbour information. To the best of our knowledge such a solution for reliable multicast communication in narrowband mobile ad-hoc networks is not yet available. The specific performance measure is the coverage probability, i.e. informing all hidden nodes to avoid interference caused by simultaneous transmissions. Furthermore, the portion of hidden nodes that cannot be covered is also studied.

The remainder of this paper is organised as follows: Section II describes and also evaluates the auxiliary node selection in the NBWF reference system. In Section III the proposed simplified node selection algorithm is described and compared to the reference algorithm. Finally, Section IV concludes the paper.

II. Reference System

The primary objective of the NATO NBWF project is the specification of a protocol stack specifically for MTNs. To the best of our knowledge NBWF is the only approach to date considering the majority of critical aspects (large coverage, robustness against jamming, ad-hoc communications, etc) for future emergency service radio networks. Therefore it serves as reference for our investigations. During the link layer specification process, TDMA based channel access [6], [7] has been proposed taking into account the specific challenge of QoS. Furthermore, a mechanism for resource reservation has been applied based on the principle of RTS/CTS messages. Since different definitions of hidden nodes exist, Definition 1 specifies this term for the remainder of this paper.

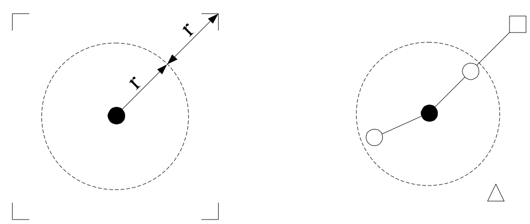
Definition 1: For any node i within a radio network, a node j at a distance of exactly two hops from node i is called a *hidden node* of i.

A. Narrowband Waveform Auxiliary Node Selection Algorithm

In the following, the algorithm for auxiliary node selection as specified in NBWF is described briefly. Based on routing information, the originator selects a finite number of auxiliary nodes (hereinafter referred to as CC-nodes) from its set of single-hop neighbours to support the resource reservation process. By transmitting a *Multicast Voice Connect Request* (MCR) message indicating the selected CC-nodes, all single-hop neighbours get informed about the imminent transmission. CC-nodes then check for possible reservation conflicts and confirm the reservation request with a *Multicast Voice Connect Confirm* (MCC) message if they do not have an active reservation for this particular resource recorded themselves. The purpose of the MCC message is both to confirm a successful resource reservation and to inform the CC-nodes' neighbours about the reservation. As some of these neighbours may be hidden nodes with respect to the session originator, this mechanism prevents them from transmitting packets using the same resources and avoids collisions. If CC-nodes have a resource requested already recorded, they responds to the MCC with a *Multicast Voice Connect Disconfirm* (MCD) message and the originator stops the transmission. Hence, the reservation protocol proposed for the NBWF shows a certain similarity to the RTS/CTS mechanism employed in IEEE 802.11. A detailed description of the node selection algorithm specified for NBWF including pseudo code is presented in [6].

B. Simulation Setup

For the evaluation of the NBWF CC-node selection algorithm a specific scenario as presented in Fig. 1a has been developed. The dimension of the square deployment area is chosen such that the distance between the centre and the corners is equal to twice the maximum transmission range of a node. For this calculation a unit disc graph is assumed where all nodes have equal transmission ranges, thus providing the best case where each corner can be covered with two hops from the centre. For each simulation run the originator (●) is positioned at the centre of the deployment area such that the probability of the network to get divided into smaller subnetworks without interconnections between them is minimised. The other (adjacent) nodes are distributed uniformly across the entire area. This scenario provides a certain probability of hidden nodes as the transmission range of each node does not cover the entire deployment area. Neighbourhood constellations of particular interest for this study are illustrated in Fig. 1b. The evaluation



(a) Simulation scenario. (b) Potential neighbourhood constellations.

Fig. 1. Overview of simulation setup. (●,○,□,△) denote originators, single-hop neighbours, dual-hop neighbours, and unconnected nodes, respectively.

considers both, various maximum numbers of CC-nodes and various maximum numbers of participants (in the following referred to as *network sizes*). For every combination of the number of CC-nodes and the number of network participants, ten million network topologies have been simulated to achieve a desired statistical confidence level. Network graphs, i.e. neighbourhood matrices have been calculated based on a radio channel consisting of a distance-dependent path loss model [4], [8] in order to generate a system model close to reality.

C. Evaluation

1) The Impact of Hidden Nodes: Initially, network constellations for various network sizes have been studied. Here, the amount of hidden nodes (with respect to the single originator) is of major interest. Fig. 2 shows the average number of hidden nodes normalised to the prevailing network size. As the probability of dual-hop neighbours increases with increasing network size, the number of hidden nodes also increases. This is due to the fact that only nodes within the reception range of the originator's single-hop neighbours, but not within

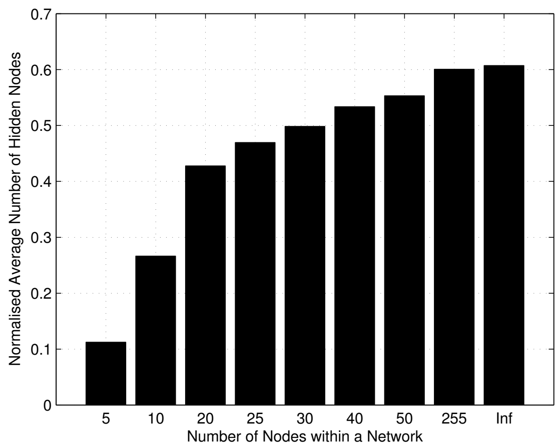


Fig. 2. Normalised average number of hidden nodes for given scenario.

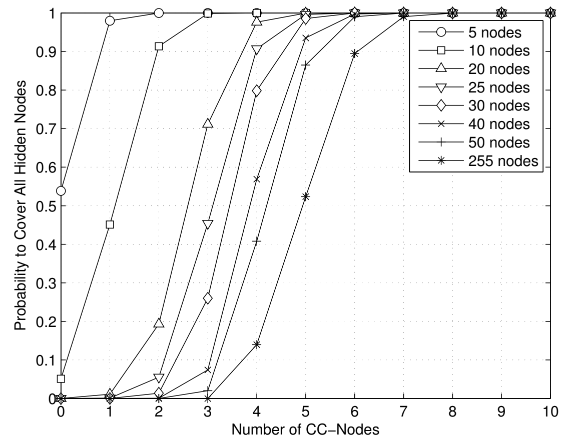


Fig. 3. Probability to cover all hidden nodes vs. number of CC-nodes for NBWF algorithm assuming perfect knowledge of network topology.

the reception range of the originator might be hidden nodes. Owing to the finite size of the deployment area the slope for smaller network sizes (five to 20 nodes) is significantly larger compared to medium and large network sizes (20 to 255 nodes). As the network size tends to infinity, the normalised average number of hidden nodes $\mathcal{H}$ within a network can be written as

$$\lim_{N_\# \to \infty} \mathcal{H} = 1 - \frac{\mathcal{C}}{\mathcal{D}} \qquad \mathcal{C} < {}^{\pi}\!/_{4}\mathcal{D} \ , \tag{1}$$

where $N_\#$ represents the network size. $\mathcal{C}$ and $\mathcal{D}$ describe the circular area covered by the originator and the entire square deployment area, respectively. Additionally, if the originator is centred within $\mathcal{D}$, (1) is valid only if the radius of $\mathcal{C}$ is lower or equal to half the edge length of the deployment area and therefore condition $\mathcal{C} < {}^{\pi}\!/_{4}\mathcal{D}$ applies. By applying (1), $\mathcal{H}$ is about 0.61 (cf. Fig. 2). Furthermore, the graph in Fig. 2 illustrates that for network sizes ≥ 30 the normalised average number of hidden nodes is about 0.5. The problem here is that with an increasing number of hidden nodes the packet collision probability also increases and the impact of the hidden nodes phenomenon becomes more and more challenging with increasing network size.

2) Performance with Perfect Topology Information: With perfect knowledge of network topology and depending on the maximum permissible number of CC-nodes, the NBWF auxiliary node selection algorithm achieves superior results as a sufficient number of CC-nodes will cover all hidden nodes.

For the NBWF algorithm a maximum number of four CC-nodes is proposed [6]. However, as described in [9] the proposed procedure enables rapid resource reservation but is not 100 per cent fail proof. In the following, the coverage probability is studied as to the best of our knowledge no quantitative information for the NBWF algorithm is yet available. Fig. 3 shows the probability to cover all hidden nodes as a function of the maximum permissible number of CC-nodes and for different network sizes whereas perfect knowledge of network topology is assumed. As depicted in Fig. 3, a probability of 1.0 to cover all hidden nodes is achievable for all network sizes simulated in this study. Assuming, for instance, a network size of 20 nodes all hidden nodes can be covered by employing five CC-nodes. In general, it can be shown that for an increasing network size an increased number of CC-nodes is required.

For those cases where it is not possible to cover all hidden nodes, it may be important to obtain information on the remaining hidden nodes as they may cause collisions. The average number of hidden nodes not covered normalised to the network size as a function of the maximum permissible number of CC-nodes is shown in Fig. 4. Again, a connection between

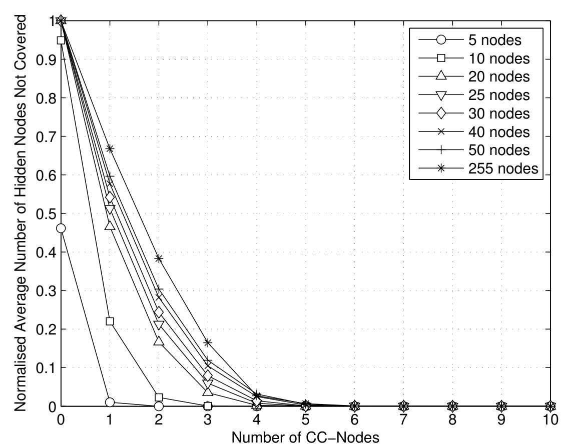


Fig. 4. Normalised average number of hidden nodes not covered vs. number of CC-nodes for NBWF algorithm assuming perfect knowledge of network topology.

the network size and the impact of hidden nodes is obvious. However, the graph illustrates that for all given network sizes and for a maximum permissible number of four CC-nodes only a small portion of hidden nodes (0.035) remains uncovered. By increasing the number of CC-nodes to five the normalised average number of uncovered hidden nodes drops below 0.01. A key finding of this study is that not only the probability to cover all existing nodes is of major interest but also the amount of hidden nodes remaining is of equal significance as these nodes may still cause interference. It should be mentioned that in cases where a network realisation does not contain hidden nodes it will be treated as if all hidden nodes have been covered. Hence, the graphs for small networks (five and ten nodes) show different initial values for zero CC-nodes compared to larger network sizes.

Finally, it should be noted that the probability of *not* covering all hidden nodes differs from the probability of a collision between two signals as this probability is given by

$$P_{\text{Collision}} = (1 - P_{\text{HN covered}}) \cdot [1 - (1 - P_{\text{Signal}})^{n_{\text{L}}}], \quad (2)$$

where $P_{\text{HN covered}}$ represents the probability to cover all hidden nodes, n_{L} is the number of hidden nodes remaining, and P_{Signal} provides the probability that a node is transmitting. The results presented in Figs. 3 and 4 demonstrate that a maximum permissible number of four CC-nodes as proposed in [6] seems to be appropriate provided perfect knowledge of network topology is available.

3) Performance with Imperfect Topology Information: As mentioned before, the NBWF algorithm is able to achieve superior results only for the case where perfect knowledge of network topology is available. In real radio networks it is rather unlikely that such perfect information is available at all times. Particularly in the case of MTNs with generally high mobility and poor radio channel conditions (due to shadowing and interference) such perfect information is even more unlikely. Taking this into account as well as assuming typical delay in distributing neighbourhood (i.e. routing) information, a certain amount of misinformation (due to missing or outdated information) has to be considered. In the following, 25 per cent of network topology information is assumed to be incorrect.

In Fig. 5 the probability to cover all hidden nodes as a function of the maximum permissible number of CC-nodes is presented. As can be seen, selection algorithm performance is significantly influenced by the percentage of imperfect topology information and network size. Small networks consisting of five to 20 nodes experience only a moderate loss in performance. For both medium (20 nodes) and large (255 nodes) networks degradations caused by imperfect topology information is more obvious. Again, assuming a network of medium size consisting of 20 nodes as well as a maximum permissible number of four CC-nodes, the probability to cover all hidden nodes is about 30 per cent less compared to the case where perfect knowledge of network topology is provided.

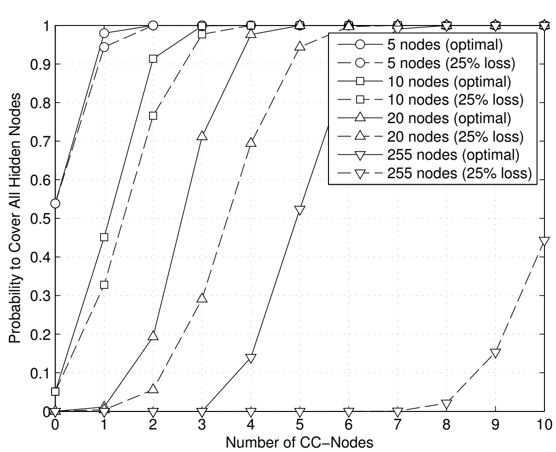


Fig. 5. Probability to cover all hidden nodes vs. number of CC-nodes for NBWF algorithm comparing both perfect and imperfect knowledge of network topology.

A similar behaviour can be observed for the average number of uncovered hidden nodes normalised to the network size as a function of the maximum permissible number of CC-nodes (see Fig. 6). A similar drop in performance can also be observed, which is evident from the increasing number of remaining uncovered hidden nodes. Degradation due to imperfect topology information increases as the network size increases. Providing a maximum permissible number of four CC-nodes and a network consisting of 20 nodes the normalised portion of uncovered hidden nodes remaining is increased by a factor of five compared to the perfect case.

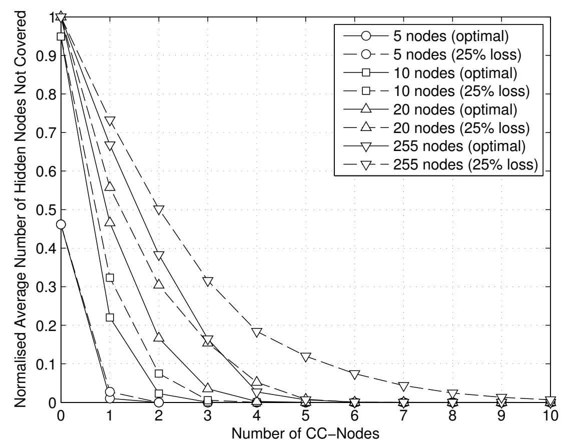


Fig. 6. Normalised average number of hidden nodes not covered vs. number of CC-nodes for NBWF algorithm comparing both perfect and imperfect knowledge of network topology.

As is evident from these results, for the NBWF algorithm imperfect knowledge of the network topology results in a significant drop in performance. Hence, for the evaluation of the approach presented in Section III the results with imperfect topology information are used as reference.

III. Simplified Approach

In general, information on network topology is distributed as routing information in terms of *HELLO* messages (HM). These messages contain information about single-hop neighbours, i.e. their network addresses, channel qualities, etc. Each node receiving HMs from its single-hop neighbours is able to obtain knowledge about their dual-hop neighbours. However, one issue is the delay in distributing this information. Even the optimistic case where each node is able to transmit its entire HM once within a TDMA superframe, it takes (at least) two superframe cycles to obtain information about all existing dual-hop neighbours. A superframe structure offering each node a defined (minimum) bit rate to transmit topology information clearly scales with the number of network participants. This may lead to a major challenge as increase in network size implies larger superframe cycles, which involves the risk that topology information is not up to date and therefore partly erroneous. Hence, an algorithm based on both limited and also reliable information is preferable. In the following, such an algorithm utilising geographical information is described.

A. Necessary Preconditions

In contrast to civil communication systems, for MTNs and trunked radio systems used by emergency services it can be assumed that nodes distribute information about their geographical location within small intervals. For instance, in the context of military communications such information is called *Radio-based Combat Identification* (RBCI) or *Blue Force Tracking* (BFT) to identify friendly forces. Information about the own position (here referred to as OPI) is mainly obtained by utilising a global navigation satellite system (GNSS).

The basic principle of the algorithm proposed in this section is the utilisation of data provided by a GNSS. It is assumed that each node within the entire network is transmitting a small OPI message once every superframe applying a robust transmission scheme. An OPI message contains details about a node's own geographical position as well as the network address for identification purposes. Hence, every node within the reception range is able to obtain information about its direct (i.e. single-hop) neighbours. Since the proposed algorithm relies only on topology information, which is distributed directly between adjacent nodes (i.e. single-hop neighbours) within one single superframe cycle, the total time until the algorithm is able to operate correctly is reduced by 50 per cent compared to the NBWF approach where at least two superframe cycles are necessary. Furthermore, for MTNs it can be assumed that information generated by and received directly from a single-hop neighbour will likely have both larger precision and larger integrity than from two-hop neighbours. However, the original issue of a negative impact on precision due to an increasing superframe cycle duration remains.

The following assumptions are made: it is both very optimistic and also unlikely for a real bandwidth limited MTN, suffering from poor channel conditions, that HMs of each network participant can be transmitted entirely within a single superframe. This is caused by the fact that the size of HMs is scaling with the number of single-hop neighbours. The average number of single-hop neighbours is scaling with the network size. Larger HMs need to be fragmented and these fragments are transmitted separately over several superframes. As a result, the time until the entire information required for the selection algorithm is available may significantly exceed two superframe cycles. In contrast, the size of an OPI message is constant and therefore independent from the number of single-hop neighbours. Moreover, an OPI message refers to a relatively small entity of data and hence it can be assumed that this information can be distributed (transmitted) on a single superframe basis even in very bandwidth limited cases, e.g. 25 kHz.

B. A Simplified Auxiliary Node Selection Algorithm Based on Reference Coordinates

In general, the proposed algorithm requires information on both a node's own position and the position of adjacent nodes. Additionally, a minimal signal-to-noise ratio γ_{min} as well as the maximum permissible number of CC-nodes N_{CC} has to be specified. Initially, the originator determines the single-hop neighbour s having the maximum Euclidean distance with respect to his own coordinates. For this node s a base angle ϕ is calculated which serves as an anchor for further calculations. In the following, N_{CC} equidistant reference angles are calculated starting from base angle ϕ. To completely describe the reference coordinates for the CC-nodes the maximum distance d between originator and CC-nodes is calculated. d is then defined to where $\gamma(d) = \gamma_{\text{min}}$ applies according to a distance-dependent path loss model. For the implementation presented in this paper, a path loss as described in [4] is used.

N_{CC} reference coordinates are distributed equidistantly on an imaginary circle whereas the centre of the circle is equal to the coordinates of the originator. The single-hop neighbour of the originator having the smallest Euclidean distance to a reference coordinate is then selected as CC-node. It should be mentioned that a node which has already been associated with a reference coordinate cannot be associated with other reference coordinates. The entire mechanism is presented in Algorithm 1.

Algorithm 1 Proposed Simplified CC-Node Selection

Require: Own geographical information x_0 and y_0
Require: Geographical information from the set S of single-hop neighbours
Require: Maximum number of CC-nodes N_{CC}
Require: Minimal signal-to-noise ratio γ_{min}
Find node $s \in S$ with the maximum Euclidean distance to $(x_0 \mid y_0)$
Set base angle to $\phi = \arctan\left(\frac{y_s - y_0}{x_s - x_0}\right)$
Set angle step size to $\beta = 2\pi / N_{\text{CC}}$
for $n = 0$ to $N_{\text{CC}} - 1$ **do**
  $\alpha_n = [(\phi + n \cdot \beta) \bmod 2\pi]$
  // Calculate a set A of N_{CC} equidistant reference angles
  // with respect to both ϕ and β
end for
Calculate distance d where $\gamma(d) = \gamma_{\text{min}}$
Calculate a set R of reference coordinates according to $\alpha \in \text{A}$ and d
For each reference point $r \in R$, where $x_r = d\cos(\alpha_r)$ and $y_r = d\sin(\alpha_r)$, find a node $c_r \in S$ with the minimal Euclidean distance
Select set $C = \{c_0, c_1, \ldots, c_m\} \subset S$ as CC-node(s), where $0 \leq m \leq N_{\text{CC}}$

C. Numerical Results

The graph in Fig. 7 presents the probability to cover all hidden nodes as a function of the maximum permissible number of CC-nodes for the simplified algorithm. For legibility reasons, only a subset of network sizes is shown. For small networks (five nodes) the NBWF algorithm based on imperfect knowledge of network topology shows slightly better performance compared to the proposed approach. However, for a medium network (20 nodes) the simplified algorithm achieves results comparable to the NBWF algorithm in case of imperfect topology information (25 per cent loss). A significant benefit of utilising the proposed algorithm is shown for large networks comprising 255 nodes and a maximum number of six CC-nodes. For a maximum number of CC-nodes greater than six the simplified algorithm achieves a performance which is in between the NBWF reference algorithm with loss of topology information equal to ten and 25 per cent, respectively.

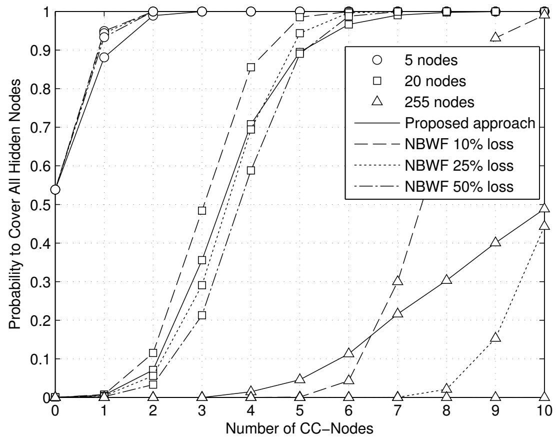


Fig. 7. Probability to cover all hidden nodes vs. number of CC-nodes for proposed simplified reference coordinate-based algorithm.

The results presented in Fig. 8 show similar tendency where the average number of uncovered hidden nodes normalised to the network size as a function of the maximum permissible number of CC-nodes is given. For small and medium networks

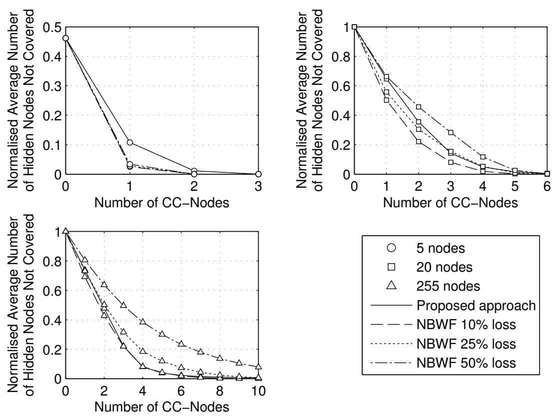


Fig. 8. Normalised average number of hidden nodes not covered vs. number of CC-nodes for proposed simplified reference coordinate-based algorithm.

the proposed approach shows a performance comparable to the algorithm of NBWF providing ten per cent misinformation. In case of medium networks the performance comparable to NBWF providing 25 per cent misinformation is achieved. When assuming large networks of 255 nodes the proposed algorithm is able to achieve a performance comparable to the NBWF reference providing ten per cent misinformation.

As can be seen, the proposed approach achieves similar performance while significantly reducing the amount of signalling data as it relies on single-hop topology information only. Moreover, the time until correct operation of the algorithm can be reduced by at least 50 per cent compared to the existing reference.

D. Combination of Algorithms

For a real system, a combination approach may be beneficial. In situations where only geographical information on single-hop neighbours is available or whenever the current knowledge of network topology seems to be insufficient the proposed algorithm can be used. For cases where topology information is assumed to be correct, the NBWF algorithm may be applied for CC-node selection.

E. Algorithm Alternatives

In order to evaluate the effectiveness of the algorithm presented before, three further approaches have been implemented. These three approaches have in common that the selection of CC-nodes is based on a neighbourhood distance criteria in order to minimise the intersection area covered by the CC-nodes. In the following, the alternative selection algorithms are described briefly. Firstly, for a maximum permissible number of CC-nodes N_{CC} all permutations of N_{CC} nodes from the set of single-hop neighbours are considered. Secondly, the pairwise distances between all nodes of the current permutation are calculated. The third step, however, is different for the three alternatives:

- Alternative 1 calculates the sum $d_k = \sum_{i=1}^{N_{\mathrm{CC}}} d_{\min,i}$ for all permutations,
- Alternative 2 calculates the squared sum $d_k = \sum_{i=1}^{N_{\mathrm{CC}}} d_{\min,i}^2$ for all permutations,
- Alternative 3 uses only the minimum distance $d_k = \min d_{\min,i}$ of each permutation k,

where $d_{\min,i}$ represents the minimum distance of node i to any of its single-hop neighbours and k denotes the number of the permutation. Finally, the permutation which results in the largest value of d_k, i.e. $d_{\max} = \max d_k$, is selected. This means, the single-hop neighbours of this permutation are designated as CC-nodes.

Fig. 9 shows the probability to cover all hidden nodes as a function of the maximum permissible number of CC-nodes. For the evaluation a network size of 20 nodes was selected as in this case the curves show the largest dynamic range. As expected, the NBWF algorithm based on perfect knowledge of network topology shows the best performance. Both the proposed algorithm and the algorithms optimising the inter CC-node distance show a performance comparable to the NBWF algorithm (25 per cent inaccurate information) but without requiring perfect knowledge of the network topology. Furthermore, as can be seen in Fig. 9, the approaches based on OPI show performance which is nearly identical. The average number of hidden nodes not covered normalised to the network size as a function of the maximum permissible number of CC-nodes is shown in Fig. 10. Once more, the best performance is provided by the NBWF algorithm based on perfect knowledge of network topology. All the approaches using OPI achieve a performance comparable to the NBWF algorithm (25 per cent inaccurate information) but again without requiring perfect topology information.

Since the algorithm is specifically designed to operate on devices with limited battery capacity, the proposed algorithm based on reference coordinates is favourable. It represents the solution with the lowest computational complexity while achieving comparable performance with respect to both the probability to cover all hidden nodes and the normalised average number of hidden nodes not covered.

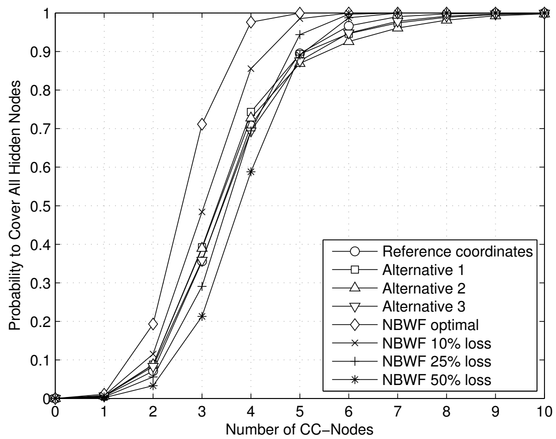


Fig. 9. Comparison of probability to cover all hidden nodes vs. number of CC-nodes for a network size of 20 nodes.

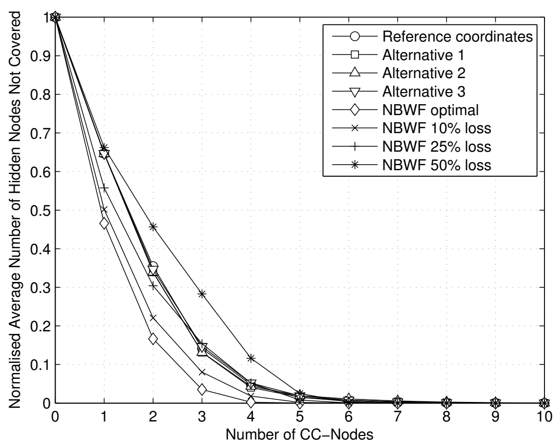


Fig. 10. Comparison of normalised average number of hidden nodes not covered vs. number of CC-nodes for a network size of 20 nodes.

IV. CONCLUSIONS

In the first part of the paper an algorithm developed for the NATO Narrowband Waveform (NBWF) has been studied where a mobile tactical network (MTN) which is strongly limited in bandwidth as well as suffers from poor channel conditions due to high mobility and interference is considered. The objective of this algorithm is the selection of auxiliary nodes which are involved in the reservation process for multicast transmissions to address both the hidden terminal and the exposed terminal problem as well as the neighbourhood capture effect. The algorithm requires perfect knowledge of network topology which can be obtained via routing information. During the investigation of the simulation scenario it has been found that the amount of hidden nodes normalised to the network size increases both significantly and non-linearly as the number of participants increases.

However, in MTNs availability of perfect network topology information is rather unlikely and selection algorithm performance providing imperfect topology information has also been studied. In this situation, the amount of misinformation is assumed to be of ten, 25, and 50 per cent. Depending on the network size, a significant reduction of the probability to cover all hidden nodes as well as a significant increase of the normalised average number of uncovered hidden nodes has been observed.

The second part of this paper has focused on the proposal of a simplified algorithm based on geographical information from single-hop neighbours. Since this information is assumed to be transmitted by each node with high frequency (e.g. once per TDMA superframe) it may be beneficial for situations where no perfect knowledge of network topology is available, e.g. (late) net entry, poor channel conditions, high mobility, etc. It has been shown that the proposed algorithm shows a performance comparable to the NBWF reference algorithm assuming imperfect topology information. The proposed solution shows performance comparable to three different algorithm variations while providing lowest computational complexity which makes it favourable especially for devices where battery capacity is critical. The proposed algorithm is capable of significantly reducing the signalling overhead used particularly for resource reservation as only single-hop neighbourhood information is required. This is of particular interest for networks with extremely limited bandwidths like NBWF. Moreover, the time until the algorithm is able to operate correctly may be reduced by at least 50 per cent compared to the existing NBWF reference as the required information is available within only one single TDMA superframe.

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