Social Choice in Sensor Networks

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Abstract. In this position statement, we argue for the use of online algorithms for social choice and group decision making in sensor networks whereby self-interested agents socially maximize their utility and preferences, which are based on variable network state. Specifically, we consider the nondictatorship principle of Arrow’s Impossibility Theorem and discuss this in the context of the Schulze voting method.

1 POSITION STATEMENT

In Arrow's seminal paper on Social Choice Theory [1], it is shown that it is not possible to construct a voting procedure that is fair in the sense of Pareto optimality, independence of irrelevant alternatives, and universality save a dictatorship. This position statement argues for the application of Social Choice Theory and, in particular, the Schulze voting method [2] to the problem of making group decisions with regard to a discrete set of Medium Access Control (MAC) layer operational parameters.

In sensors networks, determining the MAC layer operational parameters is an important task in ensuring the network meets given Quality of Service requirements subject to constraints, such as network longevity and available bandwidth. Typically, the operational parameters are optimized for peak load requirements, leading to wastage at times of low usage.

Recent work in sensor networks [3] has considered the problem of gathering global network state at the base station to optimise the MAC layer parameters in terms of bandwidth, energy efficiency, and end-to-end reliability so as to enable the network to adapt to changes in the topology and dynamic workload requirements. Determining the optimal choice over the preferences of individual agents, or nodes within the network, in relation to social choice criteria, such as the Condorcet principle, is not equivalent to aggregating the network state at the base station and then solving a global optimization problem. As such, the approach discussed here from prior work [3][4] in MAC layer parameter optimisation\textsuperscript{2}.

In contrast to prior work, we argue that mechanisms, such as the Schulze voting method, should be incorporated into sensor network applications whereby social choice properties, such as the Condorcet criterion, Pareto optimality, the resolvability criterion, and clone independence are important; that is, in applications where group decisions are made through the voting of different nodes in the network. The Schulze method operates in polynomial time and can be easily implemented with a runtime complexity of $O(n^3 + n^2v)$, where $n$ is the number of candidate options and $v$ is the number of voters, through the incorporation of a modified version of the Floyd-Warshall algorithm. Due to its low complexity, this approach could potentially be used in the development of an in network voting procedure whereby agents, in the networks of moderate size, initiate ballots at different points throughout execution. Alternatively, it could be used at the base station for large scale networks of hundreds of nodes.

In short, the Schulze voting method offers a practical approach to developing sensor network applications whereby group decision making at runtime, over a discrete set of actions or values for global network parameters, is necessary so as to ensure that the network operates efficiently. Incorporating social choice theory into sensor applications and protocols will enable the developer to ask not only does the application operate correctly, but what social choice characteristics it exhibits.

Future work will investigate the role of social choice properties in the development of a Time Division Multiple Access MAC layer. Specifically, the Schulze method will be used in conjunction with the Agent Factory Micro Edition agent programming framework [5][6] and tested on a 100 node deployment of Java-enabled motes deployed at the Tyndall National Institute, University College Cork.

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REFERENCES


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\textsuperscript{2} It would, of course, be possible to determine individual agent preferences and then use a voting procedure at the base station provided the global state of the network is known, but prior work in sensor networks does not consider this.