Agent-Based Global Transportation Scheduling in Military Logistics

Don Perugini; Dale Lambert
Defence, Science and Technology Organisation
Edinburgh, S.A., 5111, Australia
{firstname.lastname}@dsto.defence.gov.au

Leon Sterling; Adrian Pearce
Department of Computer Science and Software Engineering, The University Of Melbourne
Carlton, Victoria, 3010, Australia
{leon, pearce}@cs.mu.oz.au

Abstract

Provisional Agreement Protocol (PAP) facilitates decentralised agent planning in open and dynamic domains. PAP is implemented for our global transportation scheduling problem, allowing partial quantity and route bids, and backtracking if an infeasible solution is encountered. Current experimental results are presented, which show that our agent-based transportation scheduling implementation performs well compared with finding transportation schedules manually, which is how military logistics planners form schedules in training.

1. Introduction

Transportation scheduling is vital in military logistics. It is a complex and tedious process. Increasing deregulation and outsourcing leads to these organisations acquiring services from other organisations in order to achieve their transport goals. This results in the domain being decentralised, dynamic and open.

Military transportation goals are typically to transport large quantities of resources on a global scale. Therefore, transportation services from numerous transportation organisations are required to achieve a transportation goal, where each single transportation service (asset) may only be able to transport part of the resource’s quantity only part of the route.

Provisional Agreement Protocol (PAP) [1] facilitates decentralised planning in open and dynamic domains, which we have applied to our global transportation scheduling domain. Agents represent organisations, that cooperate via a bidding process, in order to trade transportation services, which are assembled to form a plan to achieve the transportation goal(s). PAP is based on the Extended Contract Net Protocol (ECNP) [2], but allows backtracking of single bids, and permits partial route, in addition to partial quantity, bids [1].

2. PAP and Transportation Implementation

Manager Agent (MA) requires a transport task achieved, and Transport Agents (TA) can provide transportation services (bids) to fully or partially (route and quantity) achieve MA’s task. PAP (figure 1) has 5 steps. Agents store bids and tasks for future use, and therefore, do not inform others that they are no longer required or valid unless an agent tries to use them (submit a bid for a task or grant a bid) – saves communication and allows bids and tasks to be used again during backtracking. TA are not committed to submitted bids until they are provisionally granted, and MA are committed only after they give a bid a confirm grant. MA may backtrack (go back to the previous protocol process) and provisionally reject a provisionally granted bid, if the bid resulted in an infeasible solution. MA may also provisionally reject a bid if it believes it is not suitable. If the TA submits a bid for a task that is not longer valid (e.g. achieved), then the MA sends a withdrawn message. If the MA grants a bid that is no longer valid (given a confirm grant elsewhere), or not valid now but may become valid later (given a provisional grant elsewhere, which may be rejected and become available again) then the TA sends a withdrawn or provisionally withdrawn message, respectively. TA submit only one bid (the best bid they can find for the MA), and may submit an updated bid (the next best bid) if a bid is withdrawn or rejected. Bids are accepted after the bid submission deadline as they may be considered later during backtracking. MA will grant the bid that it believes will best achieve, or partially achieve, the task. If a granted bid does not fully achieve the task, then the remaining portion that is not achieved is the new task to announce in a new spawned (next) protocol process. The process continues until the complete task is achieved – the provisionally granted bids are given a confirm grant (to secure the services in TA’s local plan) and a distributed plan is found to achieve the initial task(s).

Since PAP allows agents to enter the planning process, and send and retract tasks and bids (when agent goals and services change), at anytime, enables MA to send tasks to a set of agents without having to know exactly what services they can provide, and allows TA to send bids based on their own self interested goals, without having to release other private information. PAP accommodates planning in decentralised, dynamic and open domains.
3. Experimentation

Over 30 scenarios were executed, which were taken from military logistics training exercises. We manually determined a plan for each scenario, which is how military planners form schedules in training, and then compared the actual solution produced to that plan. Due to the complexity, the optimal plan could not be computed.

Scenarios comprise up to two MA and ten heterogeneous TA. Only ten TA were run at once because of the limited computing resources available – one PIII 900MHz to run all agents and communication software. The agents were developed using the ATTITUDE multi-agent architecture [3], and the CoABS grid was used to allow agents to communicate.

In the worst case scenario, there was a single MA with two large transportation tasks, requiring over 60 separate trips, and four TA, and hence limited available services resulting in considerable backtracking. The deadline duration was set to 2 minutes. The duration was extended to ensure that TA had more than enough time to compute bids, with our limited computing resources and relaxed bidding restrictions, before the MA progressed with the planning. A plan was produced in approximately 4 hours. Ideally, each TA will have its own processor and greater bidding restrictions, allowing it to compute bids quickly, and with the deadline duration set to say 5 seconds, providing a plan within approximately 10 minutes. Manually calculating a detailed complete plan for this scenario took us much longer than 10 minutes, while having all the information regarding TA capabilities available. In reality, this may not be the case. Therefore, these capabilities may need to be extracted from these transport organisations by the logistics planners via some means, for example, telephone, Internet, etc. This will likely add to the time required to find a transportation schedule, as well as add to the complexity for a planner to manually find a transportation plan.

The transportation plans produced were similar, or the same, to the plans we expected to be produced. There were a few minor differences. The TA occasionally took an unexpected route, primarily because the TA had a gap in its local plan such that it could perform a cheap partial route bid, where the route was a slight deviation from the direct route. In some plans, the TA may take two or more trips to transport packages, rather than one complete trip.

In the worst case scenario, the MA stored a maximum of 135 tasks and 514 bids, sent a total of 460 tasks to TA (each task sent 4 times, one for each TA), received a total of 479 bids, and communicated (sent and received) 331 speech acts (grants, rejects and withdrawn messages). The MA backtracked 18 times. The worst case TA stored 115 tasks and 113 bids, received 115 tasks and sent 179 bids (the other TA sent approximately the same number of bids as the number of received tasks) and communicated 163 speech acts. Such communication and memory requirements were easily manageable in our prototype.

Therefore, with the scenarios that were executed, our agent-based global transportation scheduling implementation compared well with the manual approach, in terms of time and quality. Even if a scenario was found that the agent-based implementation did not perform much better than doing it manually, planners can still benefit by automating this complex and tedious scheduling process – particularly by having agents to do the running around for the planner in order to extract (and assemble) transport capabilities from various transportation organisations.

4. Conclusion

PAP facilitates decentralised agent planning in open and dynamic domains. PAP is used for the global transportation planning domain, allowing partial quantity and route bids, and backtracking if an infeasible plan arises. Current experimental results are encouraging, as they perform well over current (manual) approaches to military global transportation scheduling.

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5. References

