An Agent-Based System Framework for Dynamic Mine Scheduling
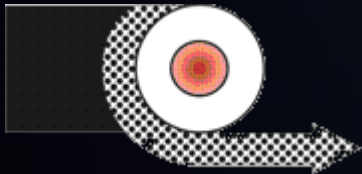
Mr. Nikolaos Ioannidis
Dr. Ioannis K. Kapageridis
Laboratory of Mining Information Technology and GIS Applications
Department of Geotechnology and Environmental Engineering
Technological Educational Institute of Western Macedonia
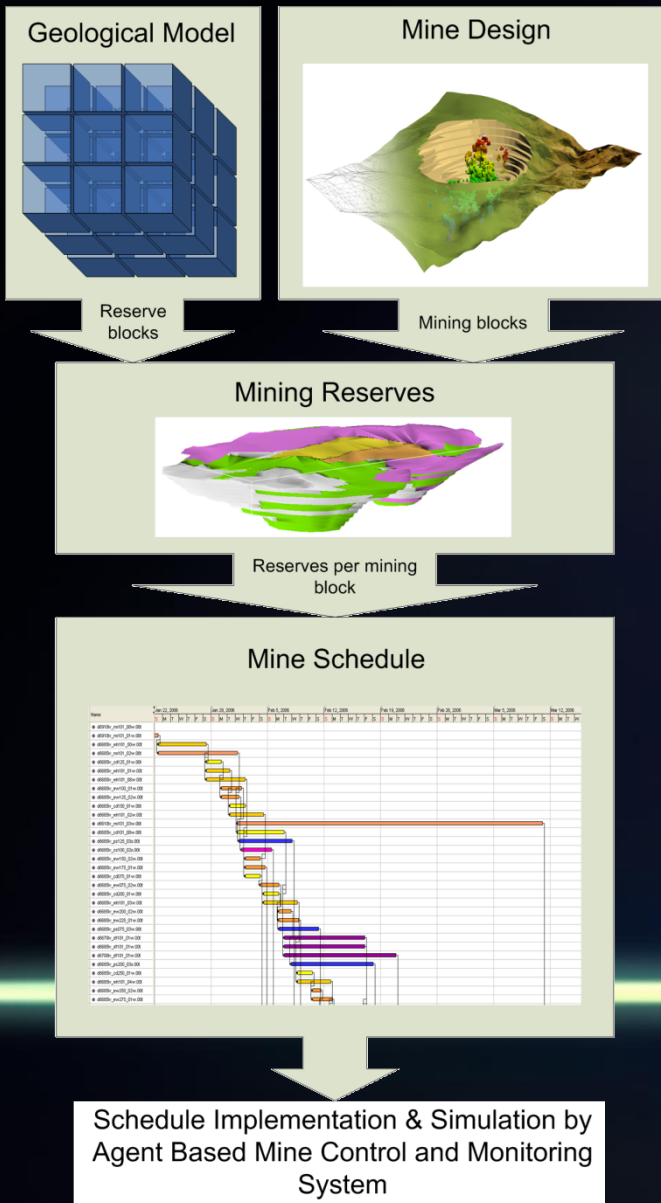Greece

Introduction

- In today's mining environment, improving production, performance, productivity and profitability is crucial.

- Traditional scheduling systems currently in use today, operate in an iterative mode constantly switching between scheduling and execution.

- However, the real world tends to change in ways that invalidate such advance schedules.

- Agent systems are being used in an increasingly wide variety of applications, including complex mission critical systems.

- In this presentation we will discuss the various components of the agent based system framework for mine scheduling.

Mine Production – The Need for Dynamic Scheduling

- Commonly, a mine develops a schedule (using Linear Programming methods) for its haulage operations using prototypical gathered data.

- However, the weather changes, a truck or loading device breaks down, the digging is particularly hard, a bin gets full because of problems with a down stream conveyor; these are all real problems affecting every single operation on a daily basis.

- The design plans and targets that have then been set are now invalidated as the system attempts to cope, quite unsuccessfully of course, with the design goal.

- Natural systems do not simply plan in advance, but adjust their operations on a time scale comparable to that in which their environment changes.

Mine Scheduling

Geological Model → Reserve blocks

Mine Design → Mining blocks

Mining Reserves → Reserves per mining block

Mine Schedule

Schedule Implementation & Simulation by Agent Based Mine Control and Monitoring System

- Scheduling is required for the development and production activities in underground and open pit mines.

- Mine schedules commonly consist of mining block entities with assigned processes.

- These schedule entities or *activities* are located in time by a start date and duration or end date.

- The process assigned to each activity has particular equipment and / or human resources associated with.

TEI
TECHNOLOGICAL EDUCATIONAL INSTITUTION
OF WESTERN MACEDONIA

Processes

Mining operations can be broken down to smaller more distinct *processes*.

A process is a representation of an entity that performs production-oriented tasks in the real world.

The process concept is central to the information model of the mine.

Because the processes are the productive or working entities of the mine, the rate or amount of mine production is measured in terms of the work the processes have done.
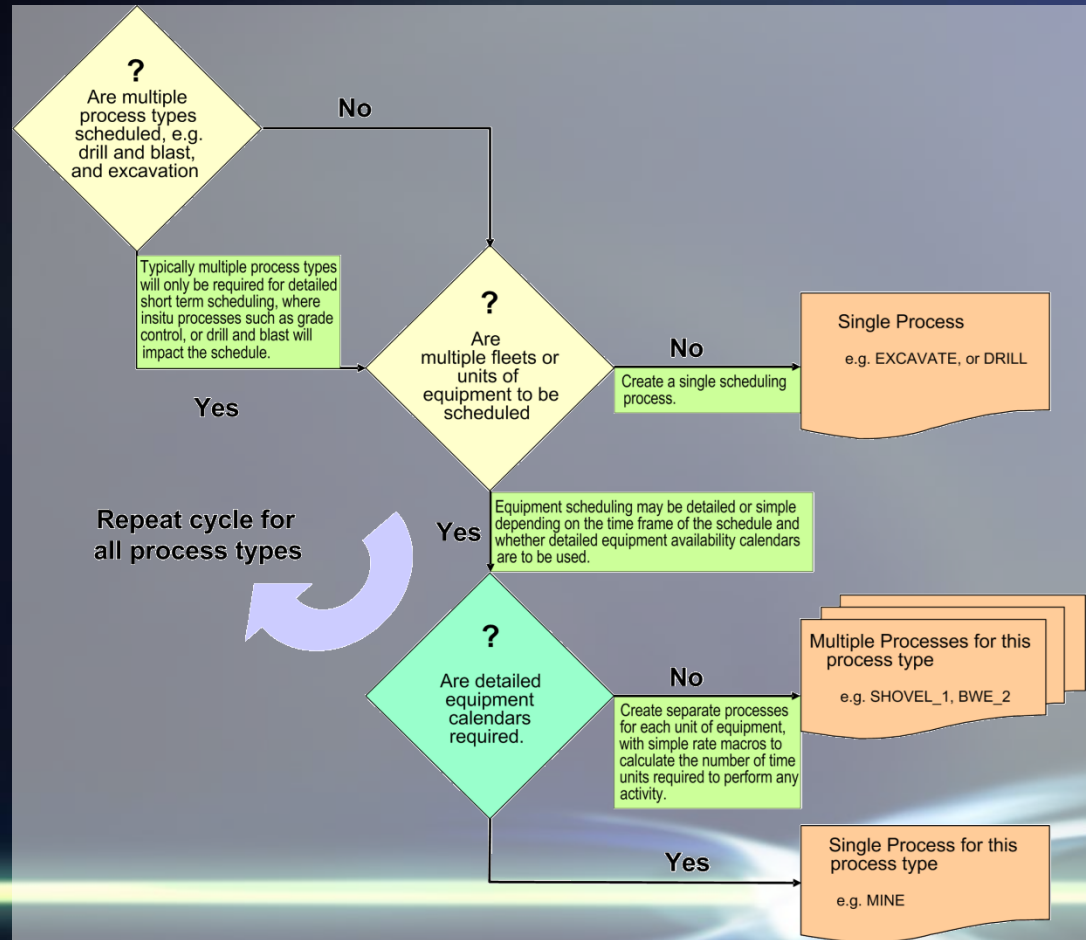
Processes

- Technically, there are no restrictions on the mine entities that can be set up as processes.

- Typically, a process is a single piece of equipment or a logical group of equipment that is a part of the productivity or daily operations of the mine.

| Open Cut or Underground Metal Mine	Underground Coal Mine	Processing or Beneficiation Plant
Truck, LHDs, Loader, Shovel, Dragline, Water Truck, Grader, Dozer, Fuel Truck, Fuel Station, Water Truck, Drill Rigs, Bolters, Pump, Crusher, Conveyor	AFC, Hydraulic Power Pack, Belt, Bin, Longwall, Development, U/G Coal, Clearance System, Shearer, Bradford Breaker, Crusher, Stage Loader, Feeder Breaker, Syntron, Continuous Miner, Shuttle Car, Roof Supports, Boot End, Monorail, Personnel Carrier, Surface Coal Clearance System, Fan	Coal Preparation, Raw Coal Transportation, Product Coal Transportation, Reagent, Air Supply, Air Systems, Bins / Hoppers, Boxes, Breaker, Centrifuge, Chute, Classifier, Controls/Instruments, Conveyor, Cyclone, Distributor, Electrical Distribution, External, Feeders, Filter, Flotation Machine, Launders, Lube Systems, Magnet, Magnetic Separators, Piping, Pump, Reclaimer, Samplers, Screens, Sieve Bends, Spiral Loops, Stacker, Sump, Tank, Thickener, Thrower, Ventilation, Water Supply

Locations

Products and other materials are mined from, hauled to, and stored in various locations within the mine.

A *location* is a representation of a point on the mine map, usually one that is a source or a store of material.

Typically, locations are in-pits where material is mined from, stockpiles at which material is stacked, bins which are filled and subsequently emptied, dump sites at which overburden is dumped, fuel tanks from where fuel is dispensed, etc.

Many of these will be of interest to the site as they are a resource from which material is taken out or accumulated in, and it may be necessary to maintain statistics on them.

TEI
TECHNOLOGICAL EDUCATIONAL INSTITUTION
OF WESTERN MACEDONIA
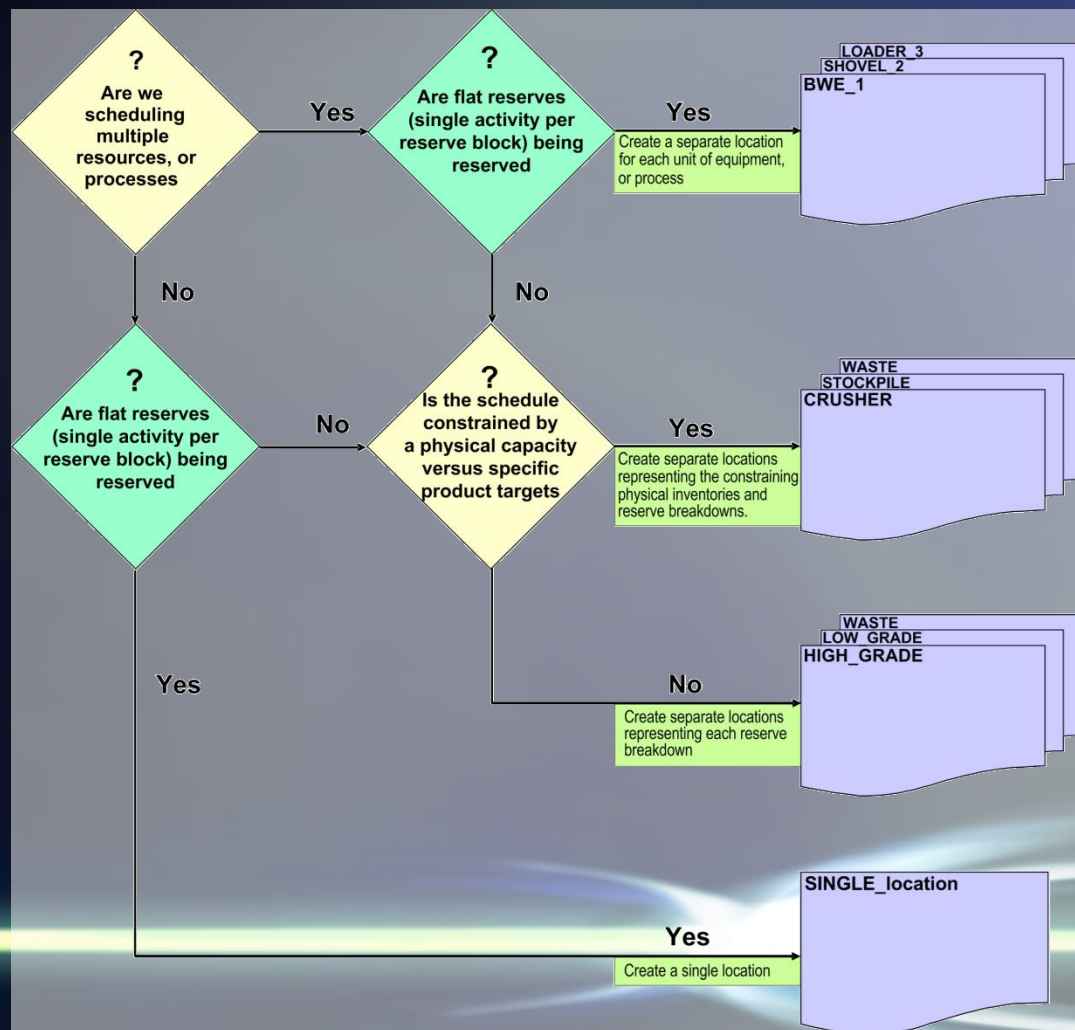
Locations

- The choice of locations depends on the actual structure of the site and various reporting and monitoring requirements.

- The interaction between locations and processes is the key to storing location production information.

- The movement of material between two locations is logged via the production of one or more intervening processes.

Open Cut Mine	Underground Mines	Processing Plant
Inpit, Dump, ROM Bin, ROM Stockpile, Inpit Stockpile, Expit Stockpile	Block, Panel, Underground Bin, Ore pass, Stope	ROM Stockpile, Product Stockpile, Circular Stockpile, Rectangular Stockpile, Reject Stockpile, Feed Bin

# Processes and Locations Interaction
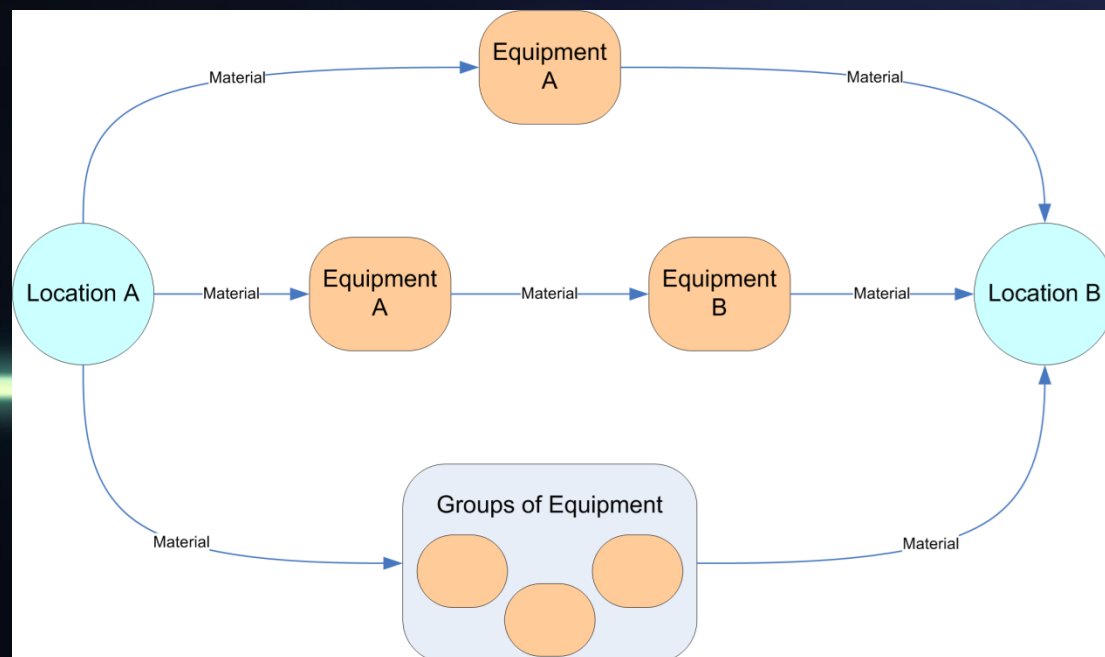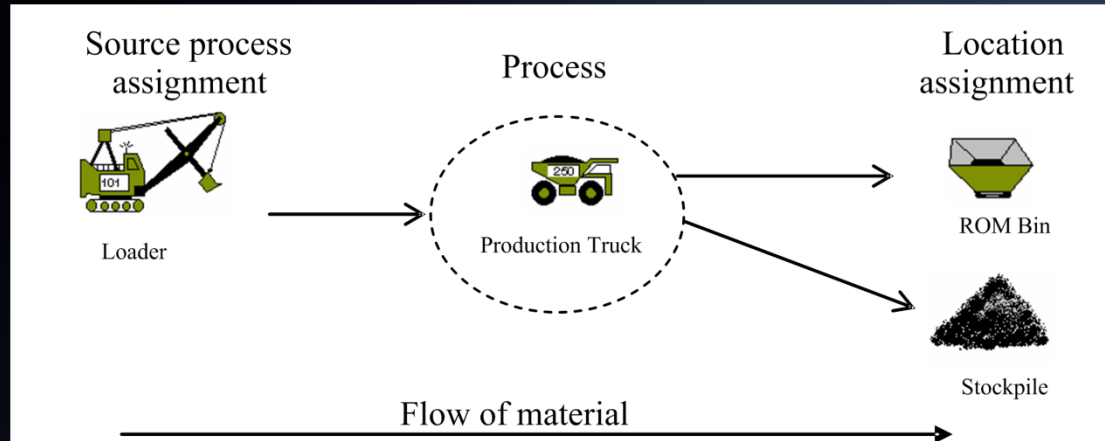
Agent Systems

- Agents are autonomous and proactive computational systems that communicate and interact through a communication language or a protocol.

- These systems can be in the form of software or combine electronic and mechanical hardware through which they become aware of their operational environment and take actions to alter it.

- They are ideal for problem solving, decision making, design and learning.

- Agent systems are the central research area of the Distributed Artificial Intelligence domain for more than three decades.

Agent Based Systems in Production Planning and Scheduling

- Production scheduling is a difficult problem, particularly when it takes place in an open, dynamic environment such as a mine.

- Because of its complexity and its dynamic nature, the scheduling problem has been widely studied in the literature by various methods.

- Agent technology has recently been used in attempts to resolve production scheduling problems.

- Agent technology has been applied to resource exploration and other mining related fields .

Agent-Based System Framework for Mine Scheduling
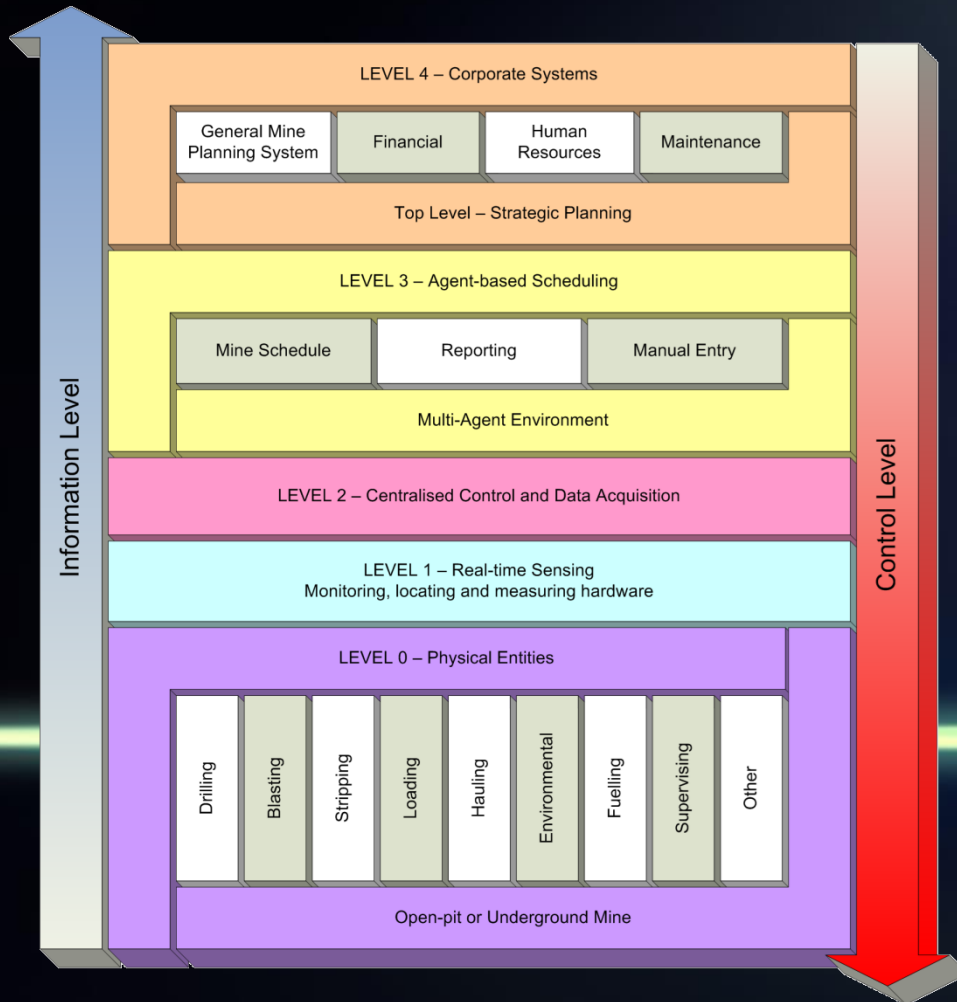
- An advantage of the agent system is its ability to receive real time information.

- This ability allows users to handle directly possible changes in the production conditions.

- In real life application, the system will be able to receive data from multiple mobile and stationary sources.

System Architecture

- The agent system for mine scheduling is essentially a group of specialized agents.
- It consists of the following agents:

  - *Static* agents for each material state alteration device.
  - *Loading* agents for each material loading device.
  - *Hauling* agents for each material hauling device.
  - *Service* agents for each device that provides service to static, loading and hauling agents.
  - *Auxiliary* agents for devices performing a function outside of the production process.
  - A *system manager* agent that receives the required schedule and generates orders.
 - An *order co-ordinator* agent for each order from the system manager agent.

Examples of Equipment and Agent Types

| Equipment	Function	Agent Type
Drill Rigs	To perform the drilling of holes within which explosives are placed	Static
Drag Lines	Used to move overburden in order to get to the underlying ore	Hauling
Shovels and Loaders	Used to dig and load waste materials or products into trucks	Loading
Trucks	Used to haul material from the pit to stockpiles, hoppers, or dump sites	Hauling
Dozers	To rip and push material into piles	Hauling
Graders	For levelling roads for the transport of material	Auxiliary
Fuel Trucks	To fuel production equipment used within the mine	Service
Fuel Stations	To fuel mobile production equipment and other ancillary equipment such as 4WDs, personnel vehicles, etc.	Service
Water Trucks	For dust control	Auxiliary
Environmental Monitoring Stations	To monitor dust, wind velocity, humidity, etc. to assist with determining when to blast, etc.	Auxiliary
Crushers	Used for sizing products appropriately	Static
Pumps	Often used for dewatering operations	Auxiliary
Power Substations	For provision of stable power to the enterprise	Auxiliary
Conveyors	For moving material within fixed locations	Hauling
Stackers	For placing products on stockpiles	Loading
Reclaimers	For removing materials from stockpiles	Loading

Real Time Information Requirements and Sources

- One of the key factors to the success of an agent based mine scheduling system is its ability to receive information in real time.

- This real time capability allows personnel to take corrective measures the moment they are aware of a change in situation rather than being made aware of the problem after the shift when productivity has already been affected.

- The system should be able to acquire data in real time from a variety of devices on board mobile and fixed equipment.

Real Time System Devices

Tilt Sensor

GPS Antenna

Radio Antenna

Computer

Control Box

CUT:44.0
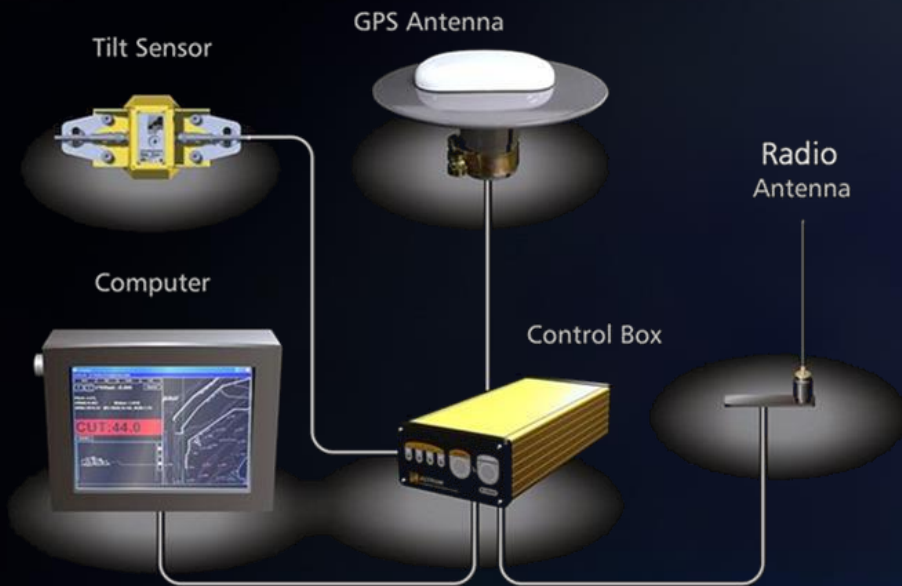
- Graphic touch screen for operator information and interaction.
- GPS or tagging systems to allow the positioning of field equipment.
- Payload monitoring systems to allow the recording of actual production quantities.
- Engine management to assist with interrogation of breakdowns, cycle information and record maintenance information.
- Programmable Logic Controllers (PLC's) to get crusher rates, power management, maintenance and control information etc.
- Dust monitors and weather stations for environmental monitoring.

Agent Interaction Protocol

Tender announcement & broadcasting

Bid broadcasting

Contract assignment
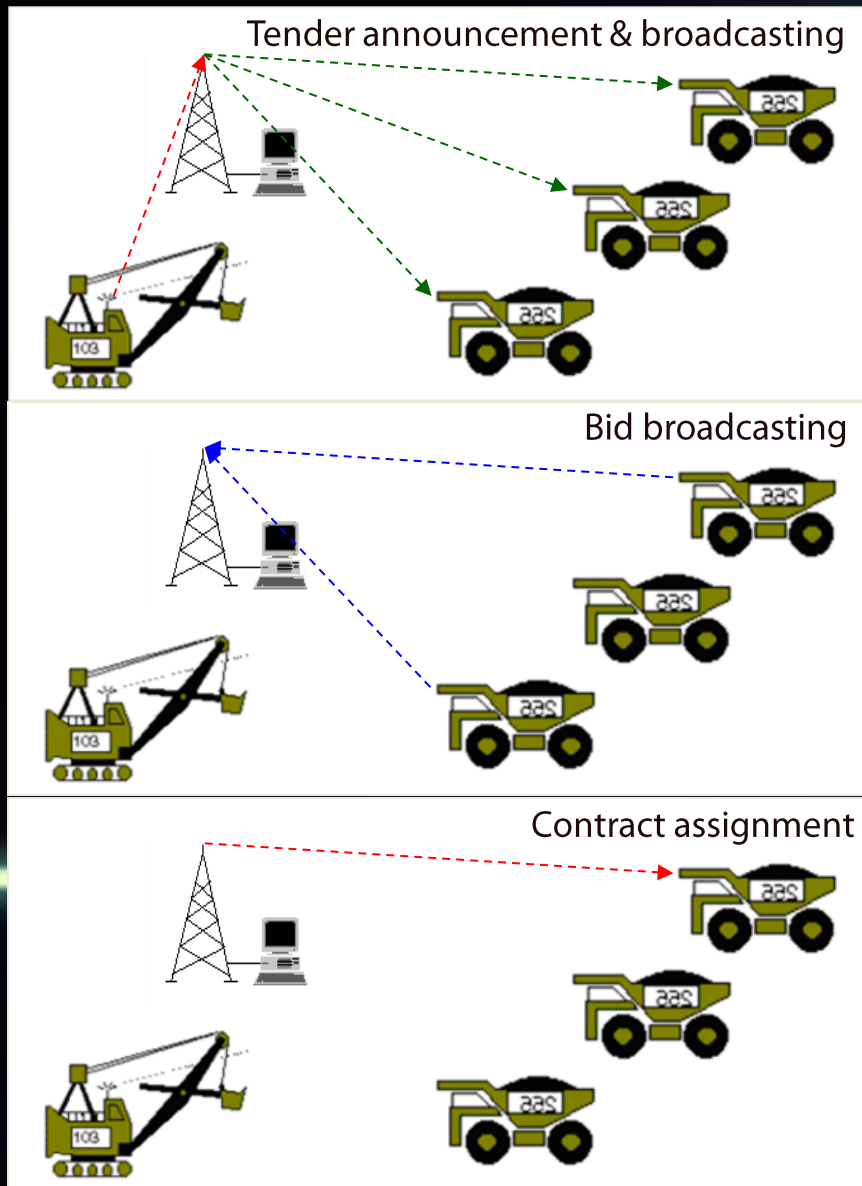
- The Contract Net protocol is used for the interaction between the various production related agents and the system manager.

- It is based on the contracting mechanism used by business to control the exchange of goods and services.

- The contract net protocol is appropriate for connection problems where we search for appropriate agents to work on a given task.

- The following actions can be performed by agents interacting with this protocol:

- call for tenders
- reception and evaluation of bids
- contract awarding to the agent that wins
- reception and evaluation of contract results after completion.

TEI

TECHNOLOGICAL EDUCATIONAL INSTITUTION
OF WESTERN MACEDONIA

System Applications

The agent based system can be used in a mining operation for the following tasks:

In virtual conditions:

1. Virtual execution of the mine schedule in order to identify possible problems.

2. Examination of the adequacy of selected equipment for the implementation of the mine schedule.

3. Equipment selection for the implementation of the mine schedule.

In real conditions:

1. Optimisation of available equipment usage.

2. Collection of production and equipment operation data.

3. Comparison and update of mine schedule with the actual situation in the mine.

TEI
TECHNOLOGICAL EDUCATIONAL INSTITUTION
OF WESTERN MACEDONIA

Conclusions

- The core competency of a mining company is the ability to create the greatest efficiency and lowest cost in meeting production goals.

- Sophisticated scheduling that addresses a multitude of constraints and variables for infrastructure, geotechnology and market conditions is required.

- The agent based system framework described in this paper can be used to develop mine scheduling solutions that are fully customizable to a number of mining scenarios and provide a much more dynamic scheduling environment than current mine scheduling applications.