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Deployment of an Distributed Strategic Material Flow Control for Automated Material Flow Systems Consisting of Autonomous Modules

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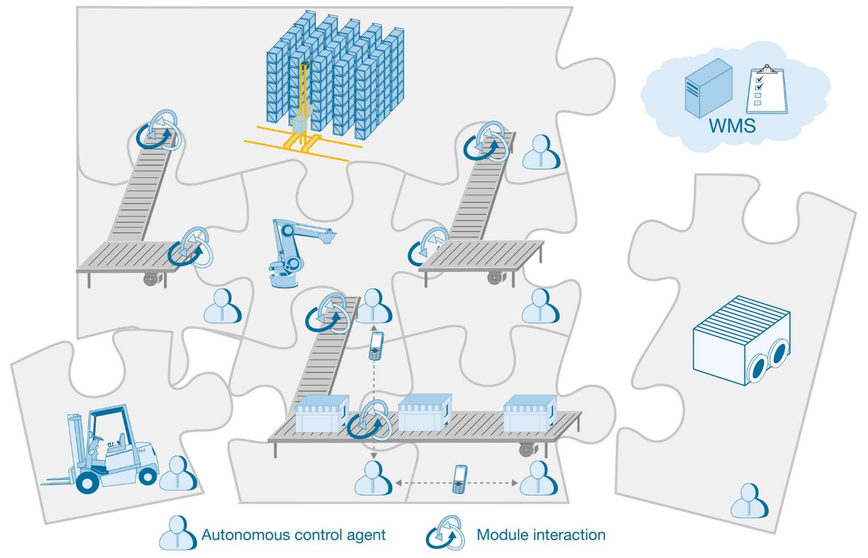
Modularized Automated Material Flow Systems (aMFSs)

Conventional aMFSs

- There are no standardized components or modules for aMFSs, so there is a great variety of heterogeneous modules on the market.
- aMFSs are mostly operated by a specialized control software and changes due to new demands require a high manual effort
- New demands arise from:
  - Changed manufacturing or logistics processes caused by new products
  - Fluctuating production volume
  - Modification of the layout in the production process due to new machinery

Convertible aMFSs

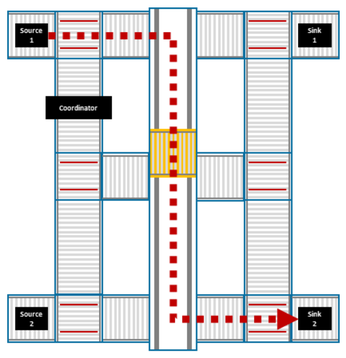
- Convertible aMFSs are characterized by providing flexibility beyond predefined limits
- Convertible aMFSs can be realized by dividing the monolithic software usually implemented on a single PLC in independent automated material flow modules (aMFMs)
- An aMFMs is defined as an encapsulated unit that performs predefined logistical functions, such as transporting or buffering
- An aMFM possesses all the necessary knowledge and software to control its hardware and to communicate with other aMFMs or superior systems.



Distributed Strategic Material Flow Control

System Architecture

- The knowledge of the layout is generated automatically during the self-configuration process of an aMFM, when an aMFM detects its neighbourhood and establishes the material flow interfaces to neighbouring aMFMs.
- The central coordinator aggregates data and provides consistent information for all aMFMs and is dynamically allocated
- Utilization of semi-static routes in aMFSs, based on the multi-label protocol switching concept used in communication networks



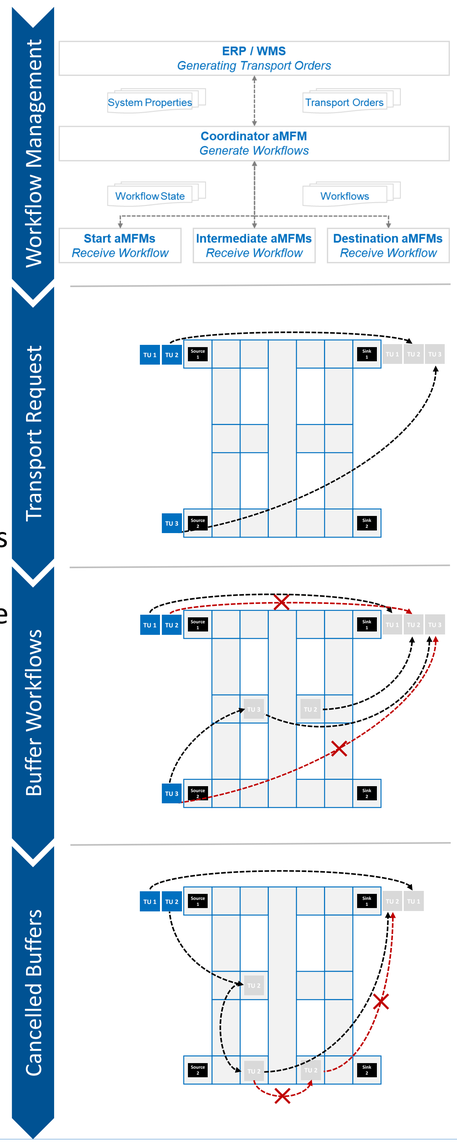
Strategic Material Flow Control

Workflow management:

- Superior systems send transport tasks to the coordinator
- The coordinator processes the transport task for a TU and generates workflows through the aMFS

There are three material flow roles for an aMFM:

1. *Destination aMFM*: The material flow control incorporates the logistical pull principle.
   - Destinations decide whether a TU is released for transport
   - Destinations cyclical check the state of the workflows and apply release criteria (e.g. sequence)
   - In the case of waiting time until the workflow may be released, the destination is responsible for selecting a suitable aMFM to buffer the TU.
2. *Start aMFM*: Start aMFMs update destinations about the current state of a workflow or request a transport.
   - The start aMFM searches for an existing semi-static route to the destination or establishes a new route.
   - For the routing a constraint-based routing algorithm is applied.
3. *Intermediate aMFM*: Intermediate destinations act as start and destination at the same time.



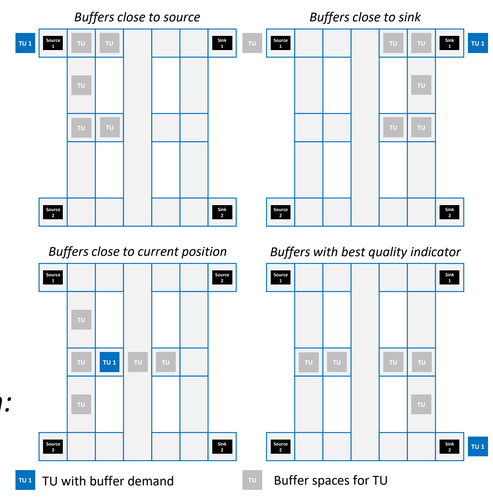
Buffer Selection Strategies

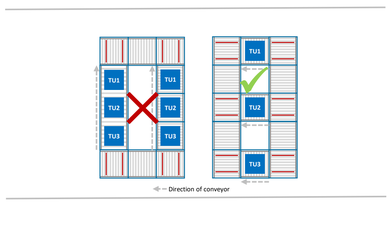
Buffer Selection

- Every aMFM can act as buffer
- The maximum and available buffer capacity are communicated to the coordinator
- The destination aMFM strategically selects a buffer set with one or more buffer aMFMs and requests an update for the set of buffers from the coordinator

Buffer Selection Strategy

1. *Select the buffer which is closest to the start:*
   The TU arrives within a short transport time at the buffer and the majority of the transport is not accomplished yet.
2. *Select a buffer which is closest to the destination:*
   The TU already accomplishes the majority of the transport to the destination.
3. *Select the buffer which is close to the current position:*
   The TU only has a short transport to the next buffer.
4. *Select a buffer in dependence of the system layout and utilisation of the aMFMs:*
   In order to evaluate the qualification of an aMFM to act as a buffer, an indicator is introduced which favours the scenarios shown on the right.





Results of the Simulation Study

- The strategy to select buffers with the introduced indicator showed the best results.
- Combination of the quality indicator with the buffer position
- The strategy solely selecting buffers after the quality indicator showed the best results

Buffer Strategy

Scenario	Buffer Quality	Quality Sinks	Quality Sources	Quality Position	All Strategies
Max. Size 5, Sequence	84%	72%	50%	35%	-6%
Max. Size 3, Sequence	152%	53%	157%	205%	68%
Max. Size 5, No Sequence	112%	93%	-42%	-39%	-8%
Max. Size 3, No Sequence	29%	29%	2%	59%	-2%
All scenarios	83%	59%	30%	55%	

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