

Parent↔Child Coordination Protocol

Overview

The Parent↔Child Coordination Protocol defines the communication patterns and state management for hierarchical coordination in the Fractal Tree system. This protocol ensures consistent state transitions, reliable command propagation, and proper error handling between parent and child nodes.

Protocol Specification

State Model

Each node maintains coordination state with its parent and children:

```
class CoordinationState(Enum):  
    DISCONNECTED = "disconnected"    # No active coordination  
    CONNECTING = "connecting"        # Establishing coordination  
    SYNCHRONIZED = "synchronized"    # Active coordination established  
    DEGRADED = "degraded"            # Partial coordination (some children unavailable)  
    FAILED = "failed"                # Coordination failure
```

Message Types

Parent → Child Messages

- COORD_INIT : Initialize coordination session
- COORD_COMMAND : Execute coordination command
- COORD_SYNC : Synchronize state
- COORD_HEARTBEAT : Maintain connection
- COORD_SHUTDOWN : Graceful shutdown

Child → Parent Messages

- COORD_ACK : Acknowledge coordination message
- COORD_STATUS : Report current status
- COORD_ERROR : Report error condition
- COORD_READY : Signal readiness for coordination
- COORD_COMPLETE : Signal command completion

Coordination Lifecycle

1. Initialization Phase

- Parent sends COORD_INIT to children
- Children respond with COORD_READY or COORD_ERROR
- Parent transitions to SYNCHRONIZED when all children ready

2. Active Coordination Phase

- Parent sends commands via COORD_COMMAND
- Children execute and respond with COORD_COMPLETE or COORD_ERROR
- Periodic COORD_HEARTBEAT maintains connection

3. Error Handling Phase

- Failed children report `COORD_ERROR`
- Parent may transition to `DEGRADED` state
- Recovery attempts or graceful degradation

4. Shutdown Phase

- Parent sends `COORD_SHUTDOWN`
- Children acknowledge and clean up
- Coordination session terminated

State Transition Rules

```
DISCONNECTED → CONNECTING: On coordination request
CONNECTING → SYNCHRONIZED: All children ready
CONNECTING → FAILED: Initialization timeout/error
SYNCHRONIZED → DEGRADED: Some children fail
SYNCHRONIZED → FAILED: Critical failure
DEGRADED → SYNCHRONIZED: Failed children recover
DEGRADED → FAILED: Too many failures
FAILED → DISCONNECTED: After cleanup
```

Error Handling

- **Timeout Handling:** Configurable timeouts for each phase
- **Retry Logic:** Exponential backoff for failed operations
- **Graceful Degradation:** Continue with available children
- **Recovery Mechanisms:** Automatic retry and manual recovery

Performance Considerations

- **Batch Operations:** Group multiple commands for efficiency
- **Parallel Execution:** Execute commands on children in parallel
- **State Caching:** Cache coordination state to reduce overhead
- **Heartbeat Optimization:** Adaptive heartbeat intervals

Implementation Notes

This is a skeleton specification for Phase 2 implementation. Full protocol details will be developed during implementation phase.

References

- Message Passing System (FT-003)
- Reliable Messaging (FT-006)
- Health/Heartbeat System (FT-007)