SPARC Containerization and Deployment

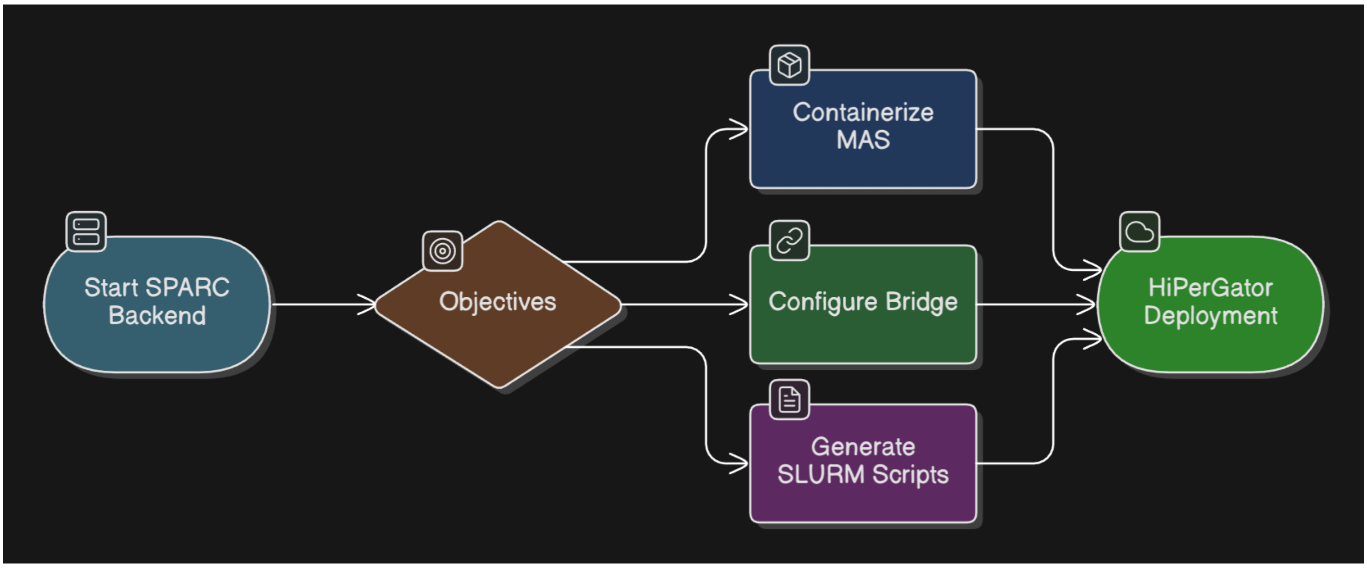
1.0 Introduction

This notebook covers the final phase: packaging the SPARC backend into portable containers and deploying them to HiPerGator with a robust networking bridge.

1.1 Objectives

1. **Containerize**: Create Dockerfiles for the Multi-Agent System (MAS).
2. **Bridge**: Configure the WebSocket-to-gRPC bridge for Unity connectivity.
3. **Deploy**: Generate production SLURM scripts for HiPerGator.

1.2 Introduction Diagram

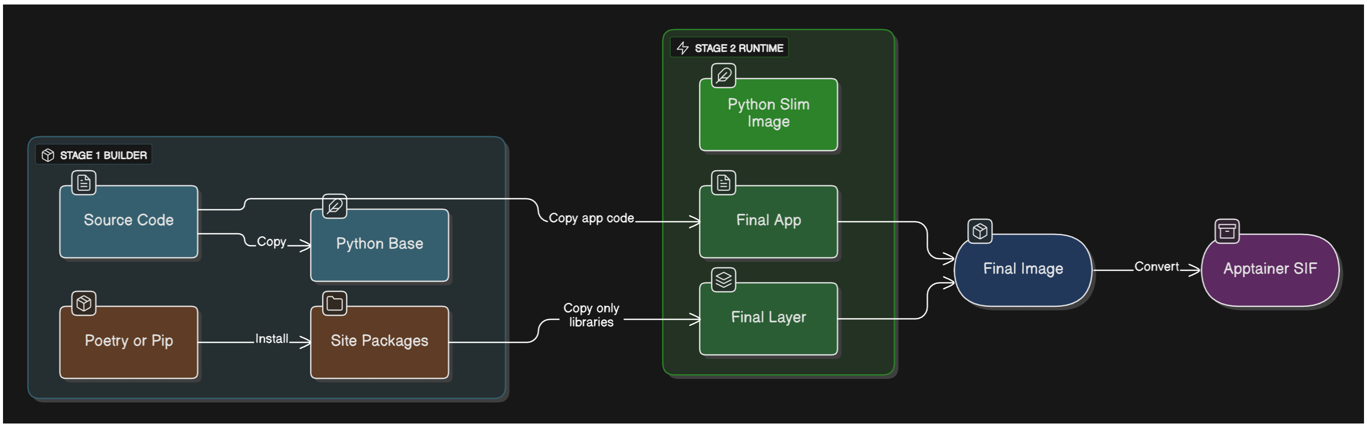


Introduction: This section sets the objectives for packaging and deploying the backend. The goal is to containerize the Multi-Agent System (MAS), configure the WebSocket-to-gRPC bridge for Unity connectivity, and generate robust production SLURM scripts for deployment to HiPerGator.

2.0 Containerization (Docker -> Apptainer)

We develop with Docker/Podman and deploy with Apptainer on HPC.

2.0 Container Build Strategy Diagram



Container Build Strategy: This flow shows the Multi-Stage Build strategy used to create secure and small containers. A "Builder" stage uses Poetry to compile dependencies, and then only the necessary artifacts are copied over to a slim "Runtime" stage. This excludes compiler tools and cache files from the final production image.

2.1 Dockerfile Definition

This script creates a `Dockerfile.mas` for the Multi-Agent System. We uses a multi-stage build strategy:

1. **Builder Stage**: Installs dependencies using Poetry.
2. **Runtime Stage**: Copies only the installed packages to a lightweight `python:3.10-slim` image. This minimizes the container size and attack surface.

2.2 Dockerfile for Multi-Agent System (MAS)

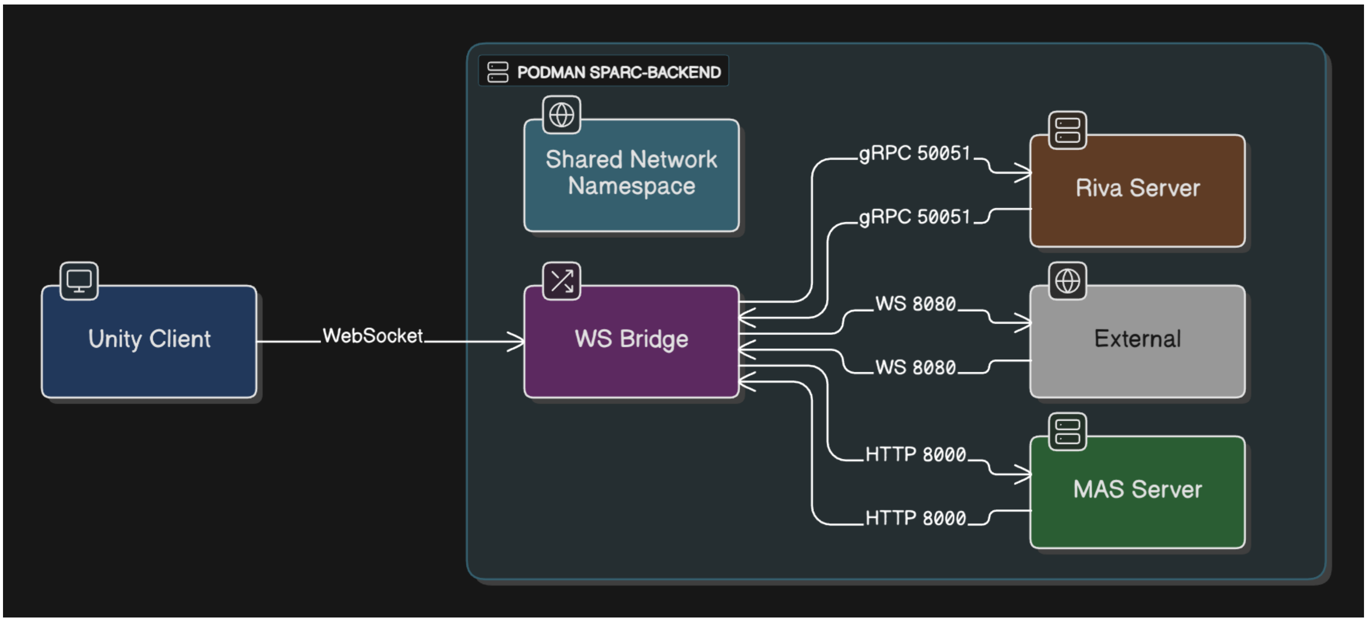
```
# 2.1 Dockerfile for Multi-Agent System (MAS)

def create_dockerfile():
    dockerfile_content = """
# --- Build Stage ---
FROM python:3.10-slim as builder
WORKDIR /app
RUN pip install --no-cache-dir poetry
COPY poetry.lock pyproject.toml ./
RUN poetry config virtualenvs.create false && poetry install --no-dev --no-
interaction --no-ansi
COPY . .

# --- Runtime Stage ---
FROM python:3.10-slim
WORKDIR /app
COPY --from=builder /usr/local/lib/python3.10/site-packages
/usr/local/lib/python3.10/site-packages
COPY --from=builder /app /app
EXPOSE 8000
CMD ["uvicorn", "main:app", "--host", "0.0.0.0", "--port", "8000"]
    """
    with open("Dockerfile.mas", "w") as f:
        f.write(dockerfile_content.strip())
    print("Created Dockerfile.mas")
```

```
create_dockerfile()
```

3.0 Local Development with Podman

Podman allows creating a 'pod' to simulate the production network namespace.

3.0 Local Development Pod Diagram



Local Development Pod (Podman): This illustrates the local development environment using Podman Pods. Unlike standard Docker containers which are isolated, a "Pod" shares a network namespace (localhost). This allows the Riva Server, WebSocket Bridge, and MAS (Multi-Agent System) to communicate locally, perfectly simulating the production environment on a developer's machine.

3.1 Podman Local Workflow

For local development, **Podman** is preferred over Docker because it allows us to create a **Pod**. A Pod shares a network namespace (localhost), allowing the separate containers (Riva, Bridge, MAS) to communicate with each other as if they were running on the same machine, mimicking the production environment.

3.2 Podman Workflow (Reference Commands)

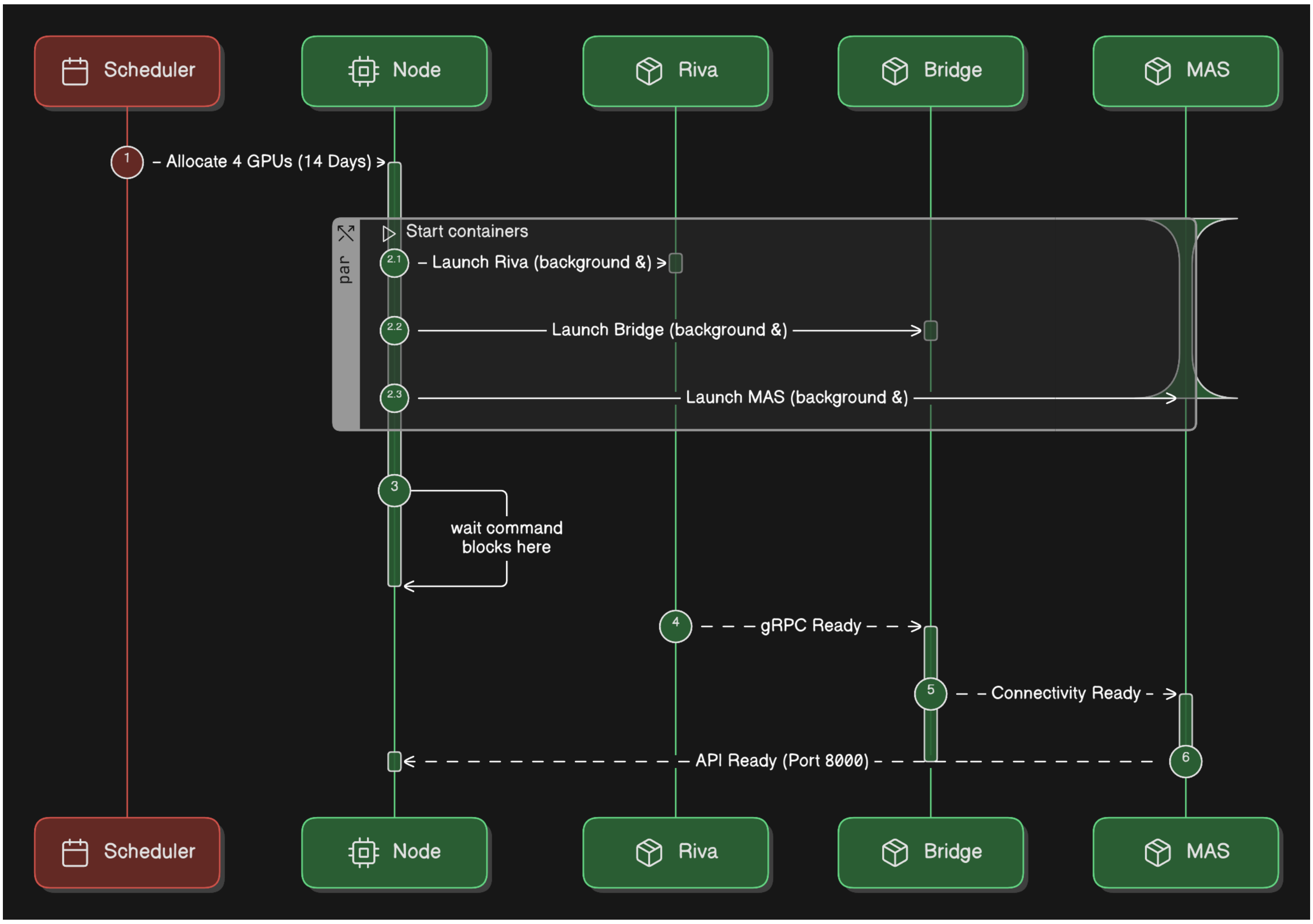
```
# 3.1 Podman Workflow (Reference Commands)
# Run these in your local terminal to test interaction between Riva, Bridge, and
MAS.

podman_commands = """
# 1. Create Pod
podman pod create --name sparc-backend -p 8080:8080

# 2. Run Riva Server
podman run -d --pod sparc-backend --name riva-server nvcr.io/nvidia/riva/riva-
```

```
speech:2.16.0-server

# 3. Run WebSocket Bridge
podman run -d --pod sparc-backend --name ws-bridge \
    -e RIVA_API_URL=localhost:50051 \
    riva-websocket-bridge:latest

# 4. Run MAS Server
podman run -d --pod sparc-backend --name mas-server your-repo/mas-server:latest
"""
print(podman_commands)
```

4.0 Production Deployment on HiPerGator

Deploying persistent services using SLURM and Apptainer.

4.0 Production Deployment Diagram



Production Deployment (SLURM): This diagram shows the execution flow of the sparc_production.slurm script on HiPerGator. It details how the SLURM scheduler allocates resources (GPUs) and then launches three concurrent Apptainer containers in the background, keeping them alive with a wait command.

4.1 Building SIF Images

HiPerGator uses Apptainer, which requires Singularity Image Format (`.sif`) files. The commands below (commented out) show how to convert your local Docker images into SIF files using `apptainer build`. These files should be stored in the `/blue` directory.

4.2 Build SIF Images

```
# 4.1 Build SIF Images
# !module load apptainer
# !apptainer build mas_server.sif docker-daemon://your-repo/mas-server:latest
# !apptainer build websocket_bridge.sif docker-daemon://riva-websocket-bridge:latest
print("Build SIF images from Docker/Daemon sources before deployment.")
```

4.3 Production Service Launch

This function generates the `sparc_production.slurm` script. This is the critical deployment artifact that runs the system on HiPerGator. Key features:

- **Persistent GPUs**: Requests 4 GPUs on the AI partition.
- **Background Processes**: Launches Riva, the Bridge, and the MAS server as background tasks (`&`).
- **Wait Command**: The `wait` instruction keeps the SLURM job alive indefinitely, ensuring the services remain running.

4.4 Production SLURM Script Generator

```
# 4.2 Production SLURM Script Generator

def generate_production_script():
    script_content = """
#!/bin/bash
#SBATCH --job-name=sparc-production-service
#SBATCH --partition=hpg-ai
#SBATCH --nodes=1
#SBATCH --gpus-per-task=4
#SBATCH --cpus-per-task=32
#SBATCH --mem=256gb
#SBATCH --time=14-00:00:00
#SBATCH --output=sparc_service_%j.log

module purge
module load apptainer

RIVA_SIF="/blue/your_group/sparc_project/containers/riva_server.sif"
BRIDGE_SIF="/blue/your_group/sparc_project/containers/websocket_bridge.sif"
MAS_SIF="/blue/your_group/sparc_project/containers/mas_server.sif"

# Launch Services in Background
echo "Starting Riva..."
apptainer exec --nv ${RIVA_SIF} riva_start.sh &
```

```
sleep 20

echo "Starting Bridge..."
apptainer exec ${BRIDGE_SIF} riva-websocket-gateway --riva-uri=localhost:50051 --
port=8080 &

echo "Starting MAS..."
apptainer exec --nv ${MAS_SIF} uvicorn main:app --host 0.0.0.0 --port 8000 &

wait
    """
    with open("sparc_production.slurm", "w") as f:
        f.write(script_content.strip())
    print("Generated sparc_production.slurm")

generate_production_script()
```

Summary

This notebook provides a complete containerization and deployment workflow for the SPARC backend:

1. **Multi-Stage Docker Build**: Minimizes container size and security vulnerabilities by separating build and runtime stages.

2. **Local Development with Podman**: Uses Podman Pods to create a shared network namespace that simulates the production environment on a developer's machine, allowing all services to communicate via localhost.

3. **Production Deployment on HiPerGator**:

    - Converts Docker images to Apptainer SIF format for HPC compatibility
    - Uses SLURM job scheduling to allocate GPU resources
    - Launches services as persistent background processes
    - Includes Riva Speech Server, WebSocket-to-gRPC bridge, and Multi-Agent System

4. **Key Components**:

    - **Riva Server**: Handles speech processing tasks
    - **WebSocket Bridge**: Enables communication between Riva and Unity frontend via WebSocket
    - **MAS Server**: Runs the trained agents for handling interactions

The deployment is fully containerized, reproducible, and scalable on HPC infrastructure.