



РЕПУБЛИКА БЪЛГАРИЯ
МИНИСТЕРСТВО НА ОБРАЗОВАНИЕТО И НАУКАТА
ИЗПЪЛНИТЕЛНА АГЕНЦИЯ
"ПРОГРАМА ЗА ОБРАЗОВАНИЕ"



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The First International Conference on Integration of Digital and AI-related Technologies

IntAI 2026

7-11 June 2026, Porto, Portugal.

AI-driven Digital Technologies for Crisis Management



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Presentation Outline

- Introduction
- AI across crisis phases
- Key AI technologies & crisis applications
- Case studies
- AI-based drone operation for crisis management
- Challenges & ethics issues
- Conclusions & future directions

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What is Crisis Management?

- Coordinated efforts to prepare for, respond to, and recover from emergencies.
- Managing unexpected, high-impact events
 - Natural disasters (floods, earthquakes, hurricanes)
 - Technological/industrial accidents
 - Public health emergencies (pandemics)
 - Cyberattacks
 - Conflicts and terrorism
 - Environmental crises
- Requires fast decisions under uncertainty
- Coordination across multiple stakeholders

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Crisis Management: Complexity

- Crisis management is becoming increasingly complex due to:
 - Climate change
 - Urbanization
 - Global insecurity
 - Cyber-physical threats
- AI provides new tools to anticipate, detect, and respond to crises with unprecedented speed and accuracy.

Why AI for Crisis Management?

- Large volumes of real-time data
- Human decision-making limitations
- Need for speed, accuracy, and prediction
- AI enhances crisis management by:
 - Processing massive real-time data
 - Predicting risks
 - Automating detection
 - Supporting decision-making
 - Improving resource allocation
- AI augments—not replaces—human judgment

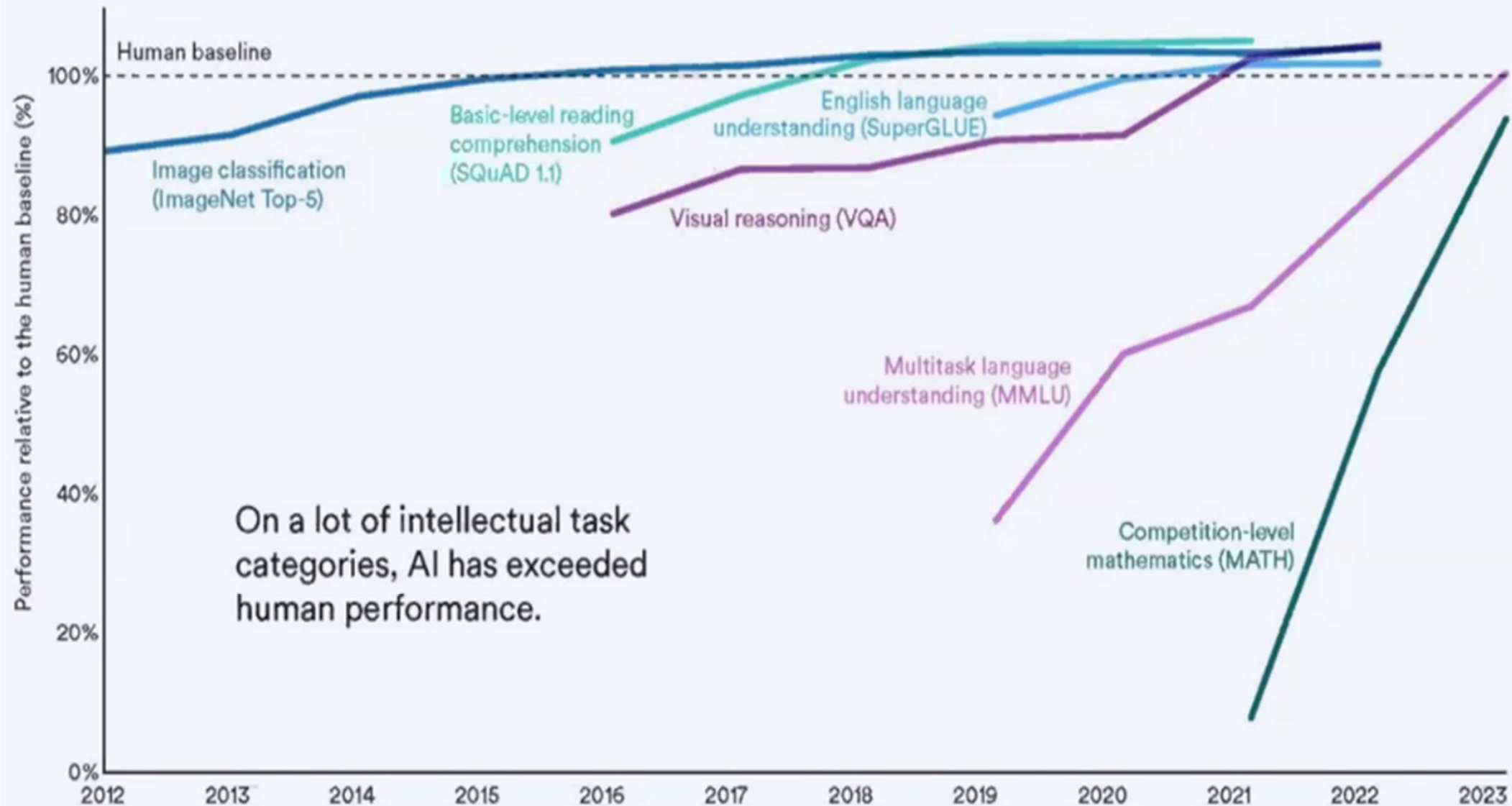
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AI Performance vs. Human Performance

Source: AI Index, 2024 | Chart: 2024 AI Index report



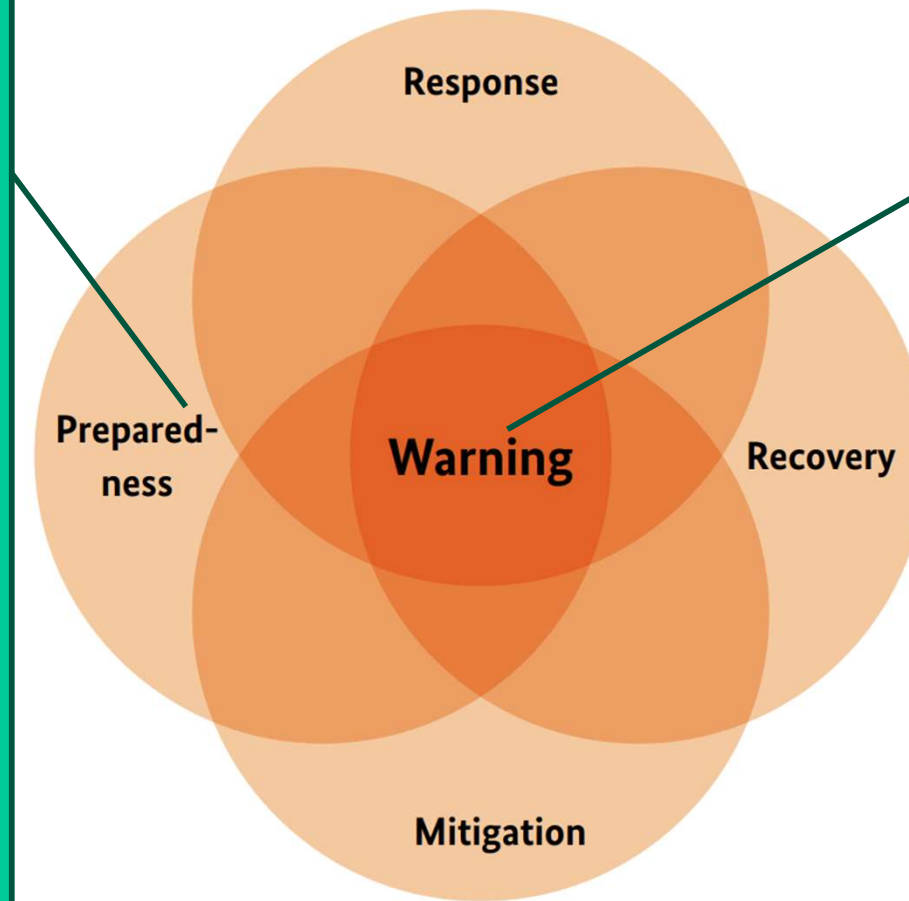
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Crisis Management: Core Phases (1)

- Prediction
- Anomaly detection
- Simulations
- Scenario modeling
- Stress testing
- Risk assessment
- Emergency planning
- Resource management
- Public awareness campaigns
- Infrastructure strengthening
- Partnerships and collaboration
- Personnel training
- Conduct exercises
- Provide personnel & material resources
- Regular review & updates



- Monitoring and early warning
- Communication
- Evacuation orders
- Public instructions
- Coordination
- Continuous updates
- Activation of emergency plans
- Community engagement
- Feedback and adjustment

Source: https://warnung-der-bevoelkerung.de/wp-content/uploads/2023/07/BBK_Warnbedarf-und-Warnreaktion_11543_barr.pdf

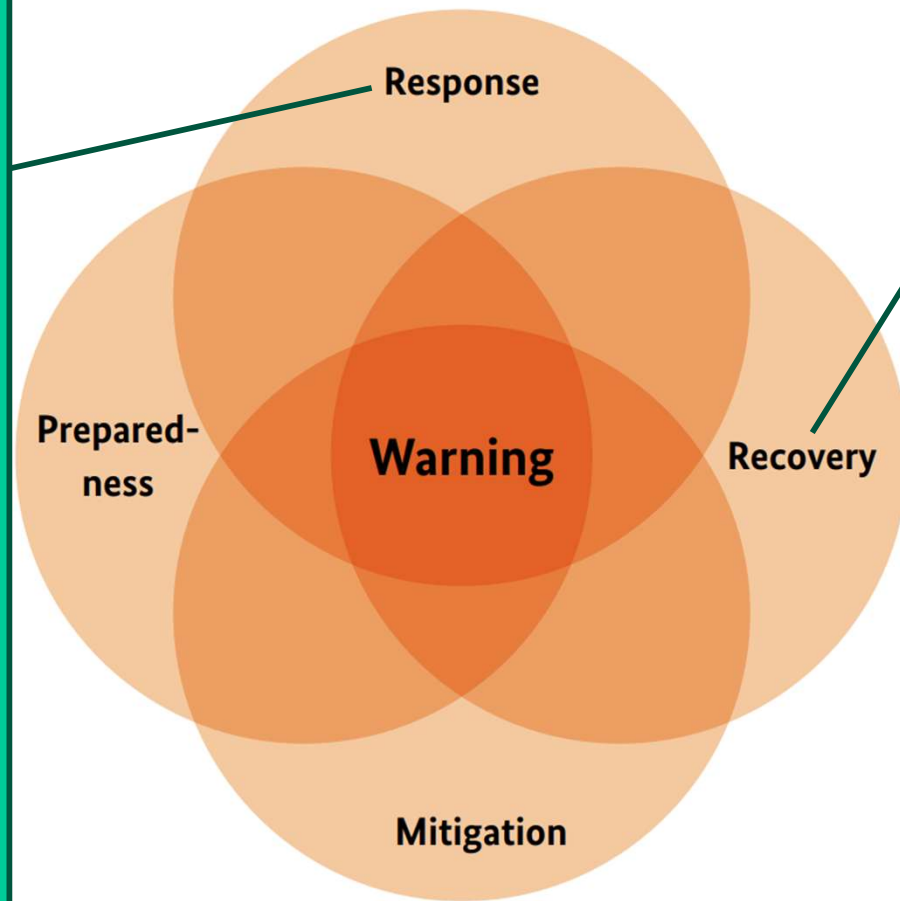
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Crisis Management: Core Phases (2)

- Real-time decision support
- Emergency services activation
- Search and rescue operations
- Medical assistance
- Evacuation and sheltering
- Communication and coordination
- Resource distribution
- Infrastructure repair
- Security and law enforcement
- Psychological support
- Damage assessment
- Public information
- Volunteer and community engagement



Source: https://warnung-der-bevoelkerung.de/wp-content/uploads/2023/07/BBK_Warnbedarf-und-Warnreaktion_11543_barr.pdf

- Damage assessment
- Restoration of services
- Debris removal
- Reconstruction
- Financial assistance
- Mental health support
- Community engagement
- Economic recovery
- Health and social services
- Mitigation measures
- Documentation and reporting

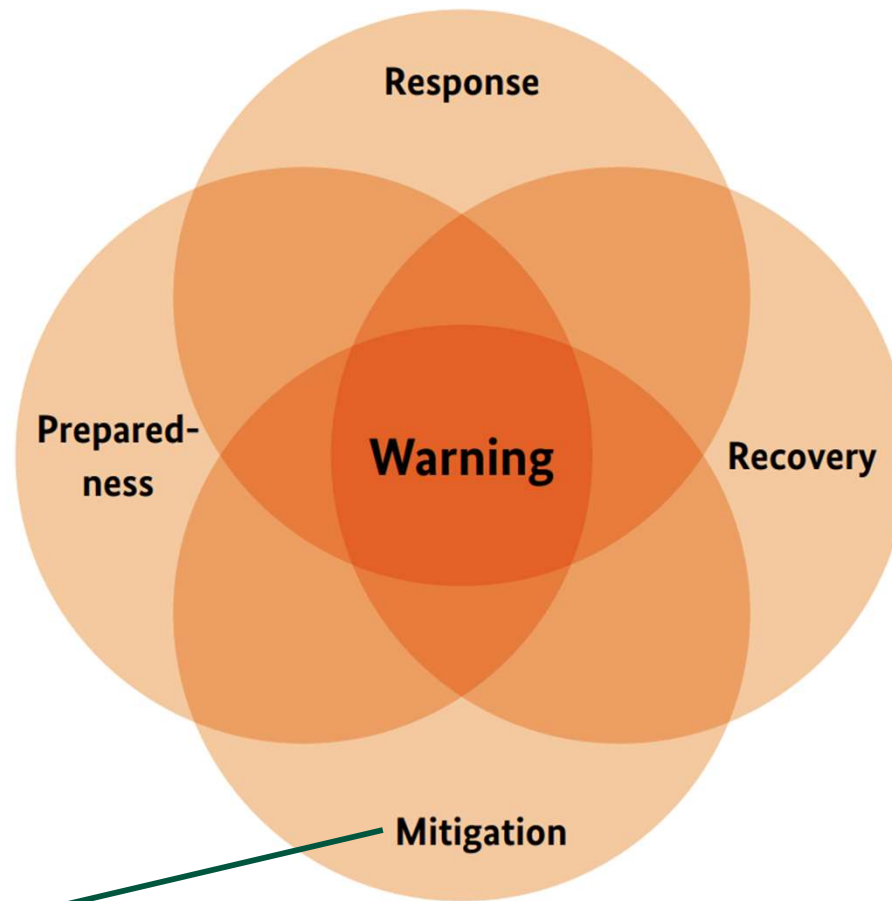
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Crisis Management: Core Phases (3)

- Implement findings
- Optimize entire processes
- Resilience optimization
- Take measures (structural & non-structural)
- Maintain & upgrade systems/networks
- Training and capacity building
- Public education and awareness
- Environmental management
- Community engagement
- Financial incentives
- R&D



Source: https://warnung-der-bevoelkerung.de/wp-content/uploads/2023/07/BBK_Warnbedarf-und-Warnreaktion_11543_barr.pdf

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AI Use: Emergency Management

- Initial assessment
 - Quickly draft initial assessment reports
 - Get information on similar past incidents for reference
- Public communication
 - Create templates for public advisories
 - Tailor messages for different audiences (public, stakeholders)
- Resource coordination
 - Organize lists of resources and contacts
 - Develop quick-access guides for team roles and responsibilities
- Media relations
 - Formulate press releases
 - Prepare Q&A for press briefings

Source: Webinar “How far should we trust AI in a crisis situation?” (25.02.2026)

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AI Use: Strategy & Planning

- Crisis strategy
 - Create step-by-step action plans
 - Explore potential outcomes of different strategies
- Stakeholder communication
 - Prepare updates & briefings
 - Personalize communication for each stakeholder group
- Logistics management
 - Create checklists for supply distribution & logistics
 - Simulate logistics scenarios
- Risk assessment
 - Updates as per new info coming in
 - Compare current crisis to historical data

Source: Webinar “How far should we trust
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AI Use: Post-Crisis Analysis & Learning

- Debriefing & reporting
 - Structure debriefing sessions
 - Compile reports on lessons learned and outcomes
- PR management
 - Draft recovery and reassurance messages for the public
 - Plan long-term communication strategies for ongoing transparency
- Training & drills
 - Develop training modules for crisis scenarios
 - Script realistic simulation exercises
- Continuous improvement
 - Analyze data to improve future crisis response
 - Identify improvement opportunities in protocols

Source: Webinar “How far should we trust AI in a crisis situation?” (25.02.2026)

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Key AI Technologies & Crisis Applications

AI Technology	Crisis Application	Examples
Machine Learning	Prediction	Flood forecasting
Computer Vision	Damage assessment	Drone imagery
NLP	Social media analysis	Misinformation detection
Robotics	Search & rescue	Autonomous drones
IoT + AI	Early warning	Sensor networks
Digital Twins	Recovery planning	City simulations

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AI Use Across Crisis Lifecycle

- Disaster prediction & early warning
 - Time-series forecasting for early warning systems
 - Graph-based models for cascading failure analysis
- Detection and situational awareness
 - Computer vision (CV) for satellite, drone, and CCTV data
- Response and resource allocation
 - NLP for emergency calls and reports
 - Emergency call triage and dispatch optimization
 - Social media monitoring for situational awareness
- Recovery and resilience building
 - Infrastructure damage assessment using remote sensing

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Real-World Use Cases: **Natural Disasters**

- Flood, wildfire, earthquake early warning systems
 - By analyzing massive datasets from satellites, IoT sensors, and global media, AI enhances predictive accuracy and speed for floods, wildfires, and earthquakes, enabling life-saving anticipatory action before disaster strike.
- Satellite imagery + CV for damage assessment
 - By comparing pre- and post-disaster images, ML models automatically map affected infrastructure, speeding up humanitarian aid and resource allocation.
- Predictive evacuation and resource staging
 - Predictive evacuation utilizes real-time environmental sensors, dynamic risk modelling, and ML to forecast disaster impacts and identify which populations need to flee.
 - Resource staging coordinates the pre-positioning of personnel, shelters, and supplies into safe zones based on these forecasts to ensure rapid deployment.
- Multi-agency coordination dashboards
 - Centralized digital platforms, integrating real-time data from disparate organizations, designed to facilitate situational awareness, resource allocation, and collaborative decision-making among different jurisdictions, emergency responders, or public service departments.

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Real-World Use Cases: **Pandemics**

- Epidemiological modeling and spread prediction
 - Using mathematical equations and statistical algorithms to simulate the transmission dynamics of infectious diseases by integrating population data, environmental factors, and contact rates, as to predict outbreak trajectories, assess health system burdens, and evaluate the impact of interventions.
- Hospital capacity and ICU load forecasting
 - Utilizing predictive algorithms and stochastic modelling to anticipate patient volume, Length of Stay (LoS), and bed availability.
- Supply chain and logistics optimization
 - Leveraging AI and predictive analytics to slash logistics costs, balance inventory levels, and reduce delivery times, as to enhance resilience, meet customer demands efficiently, and stay competitive.
- Policy impact simulation (lockdowns, mobility limits)
 - Relying heavily on AI agent-based models and mobility tracking to predict viral spread, assess strain on healthcare, and evaluate the socioeconomic fallout of keeping people at home.

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Real-World Use Cases: Critical Infrastructure

- Energy grid and telecom outage prediction
 - Proactive process, utilizing ML, AI, and sensor data to forecast system failures before they cause widespread damage, replaces reactive emergency responses with dynamic, data-driven risk management.
- Predictive maintenance (PdM) of assets
 - By continuously analyzing real-time IoT sensor data—such as temperature, vibration, and acoustics—through advanced AI algorithms and ML models, PdM identifies microscopic anomalies and degradation patterns, allowing to shift maintenance and operations from a reactive, break-fix model to a proactive strategy that virtually eliminates costly unplanned downtime, extends equipment lifespans, and optimizes operational efficiency.
- Cross-sector dependency modelling
 - Mathematical and analytical framework used to evaluate how interconnected industries, critical infrastructures, or supply chains rely on one another.

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Real-World Use Cases: **Cyber Attacks**

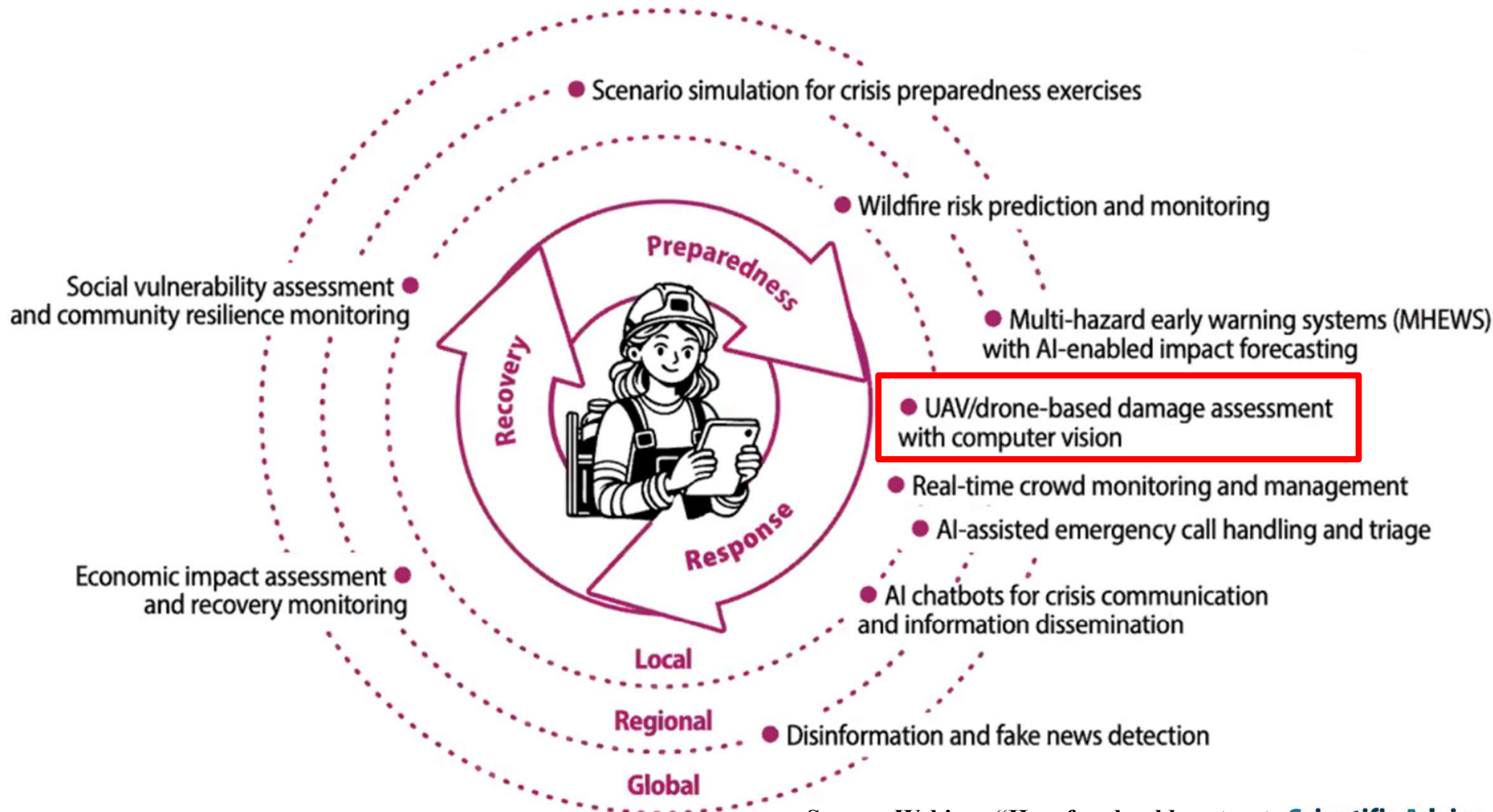
- AI-based intrusion and anomaly detection
 - Leverage ML algorithms to analyze system logs, user behavior, and telemetry in real-time.
- Automated incident triage and prioritization
 - By using AI algorithms and predefined playbooks to instantly classify, score, and route incoming alerts, it filters out false positives and adds critical business context, allowing on-call engineers to focus immediately on the most urgent threats rather than sorting through crowded queues.
- Attack propagation modeling
 - By using mathematical or computational simulation of how threats, such as malware or lateral movement, spread across a network or system, this helps security teams predict attack paths, evaluate containment strategies, and optimize resource allocation before or during an incident.
- Decision support for containment strategies
 - Balancing rapid threat mitigation with the need to maintain business continuity and preserve forensic integrity.

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AI Use in Crisis Management: Examples

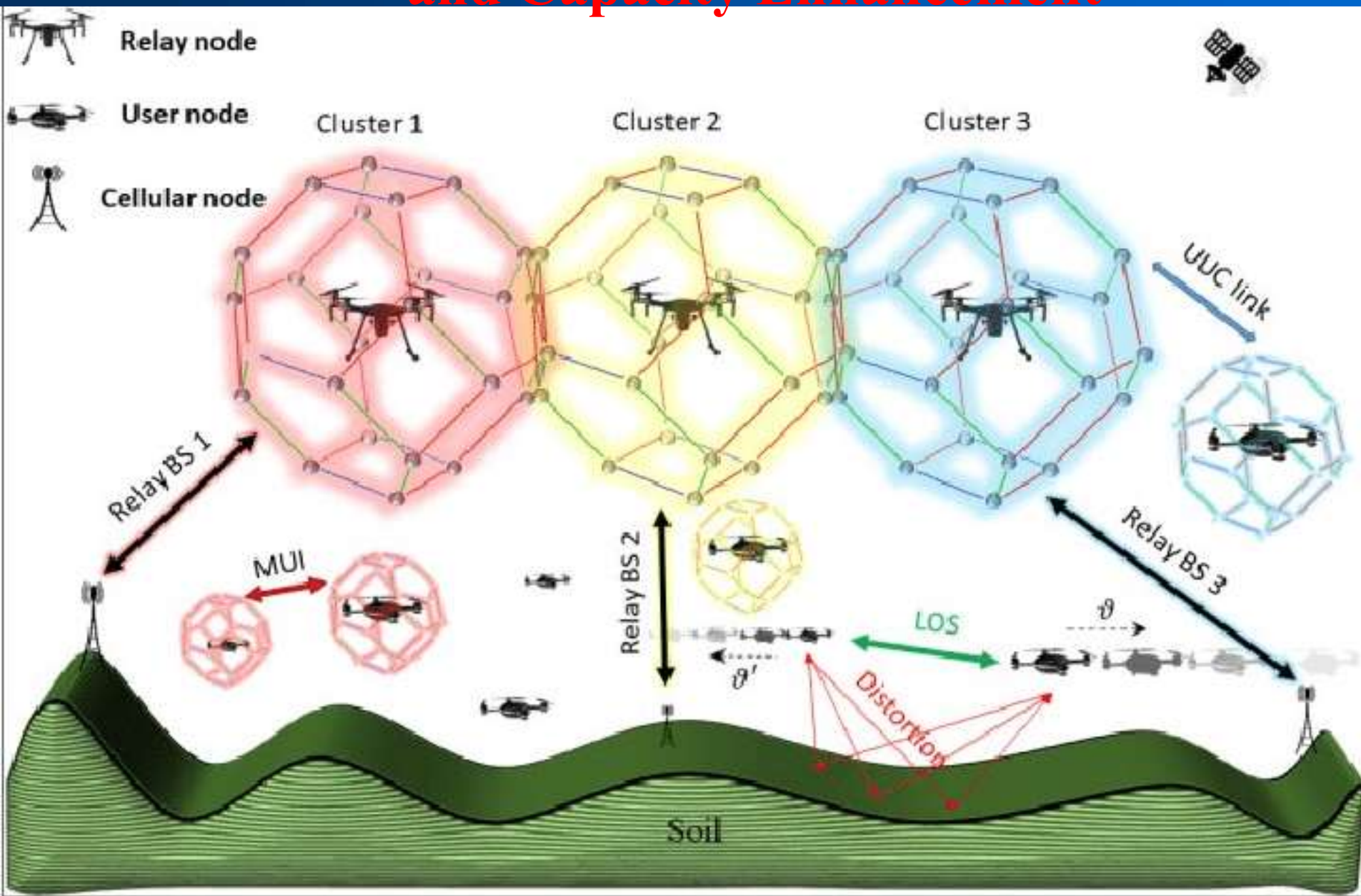


Source: Webinar “How far should we trust AI in a crisis situation?” (25.02.2026)

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Using Drones for Communication Coverage and Capacity Enhancement



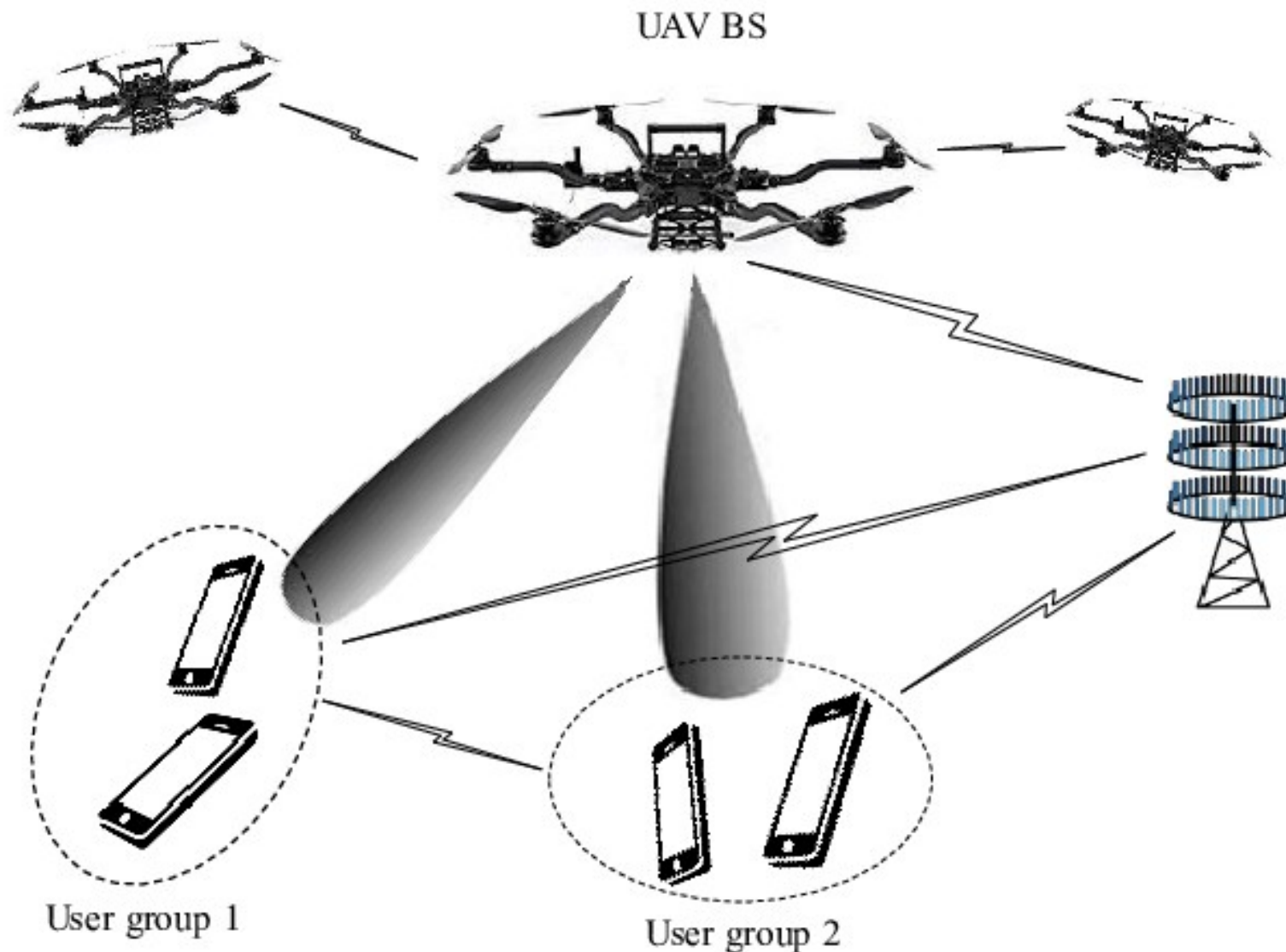
Source:
HOSSEINI
et al.: UAV
Command
and Control,
Navigation
and
Surveillance:
A Review of
Potential 5G
and Satellite
Systems.
[https://www.
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Using Drones for On-demand Communications



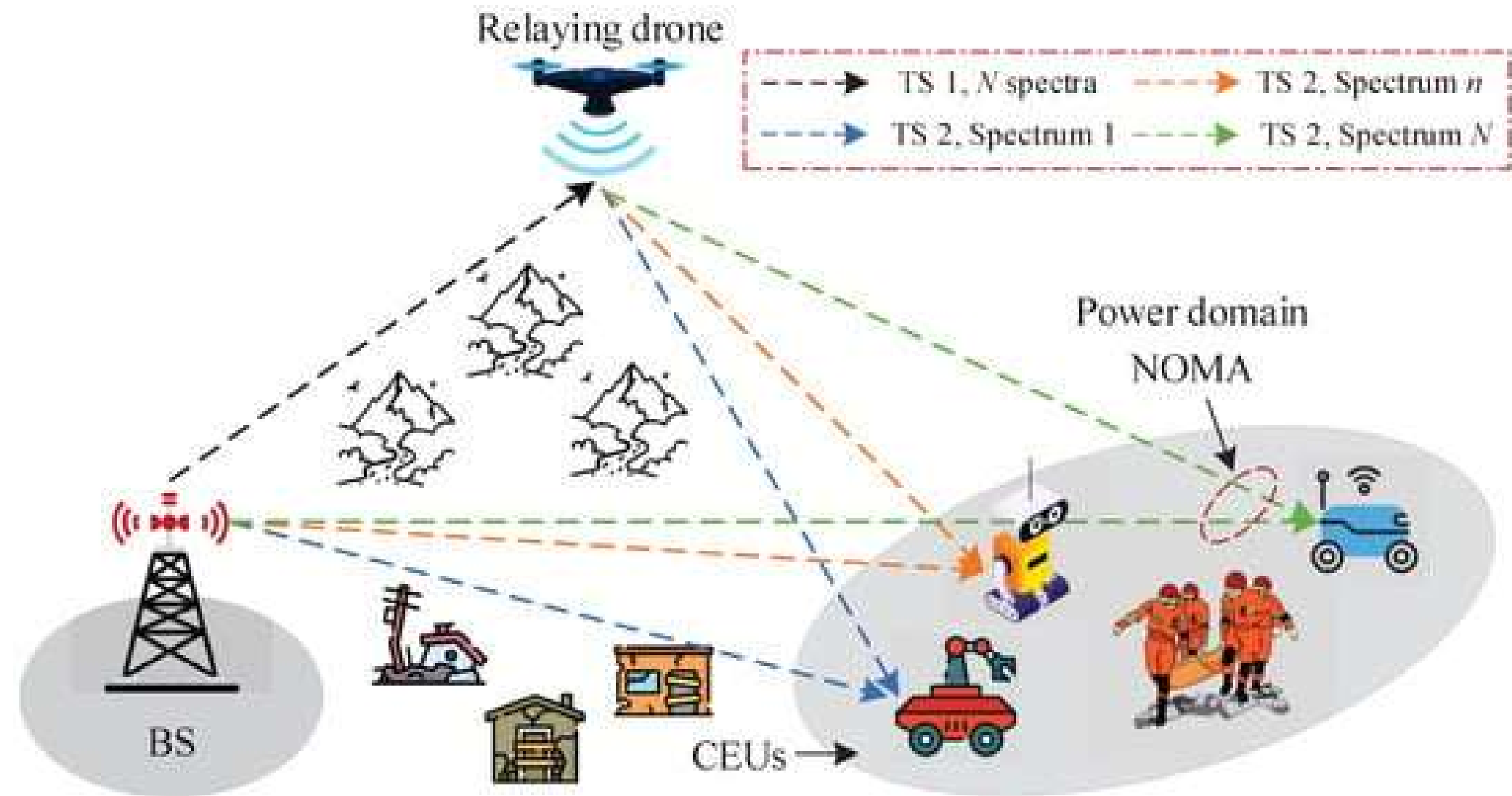
Source:
HOSSEINI et al.:
UAV Command
and Control,
Navigation and
Surveillance: A
Review of
Potential 5G and
Satellite Systems.
https://www.researchgate.net/figure/UAV-communication-entities-including-ground-air-and-space-segments_fig1_333919084

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Using Drones for Disaster Relief



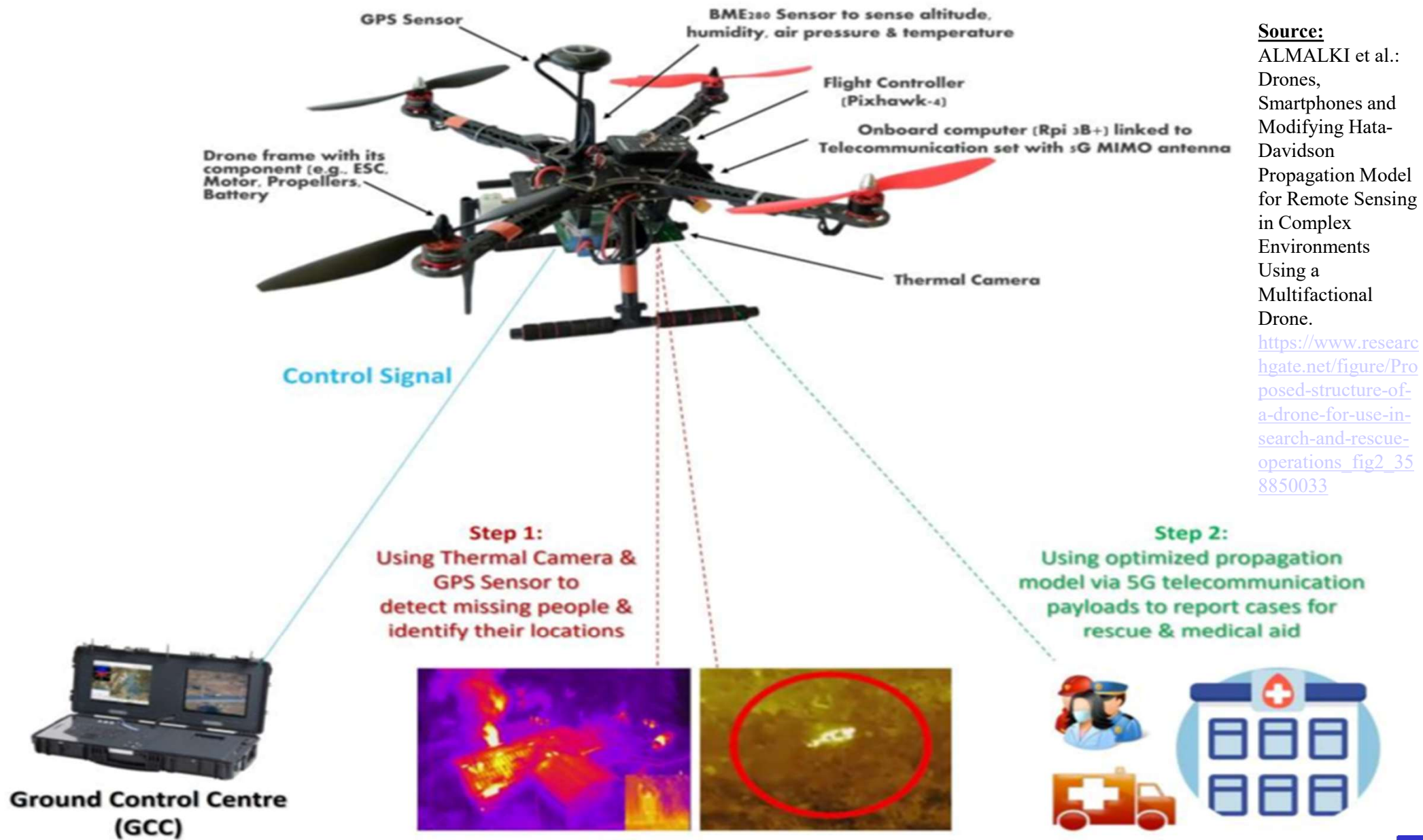
Source: LI et al.: Post-Disaster Emergency Communications Enhanced by Drones and Non-Orthogonal Multiple Access: Three-Dimensional Deployment Optimization and Spectrum Allocation. <https://www.mdpi.com/2504-446X/8/2/63>

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Using Drones for Localization, Search and Rescue

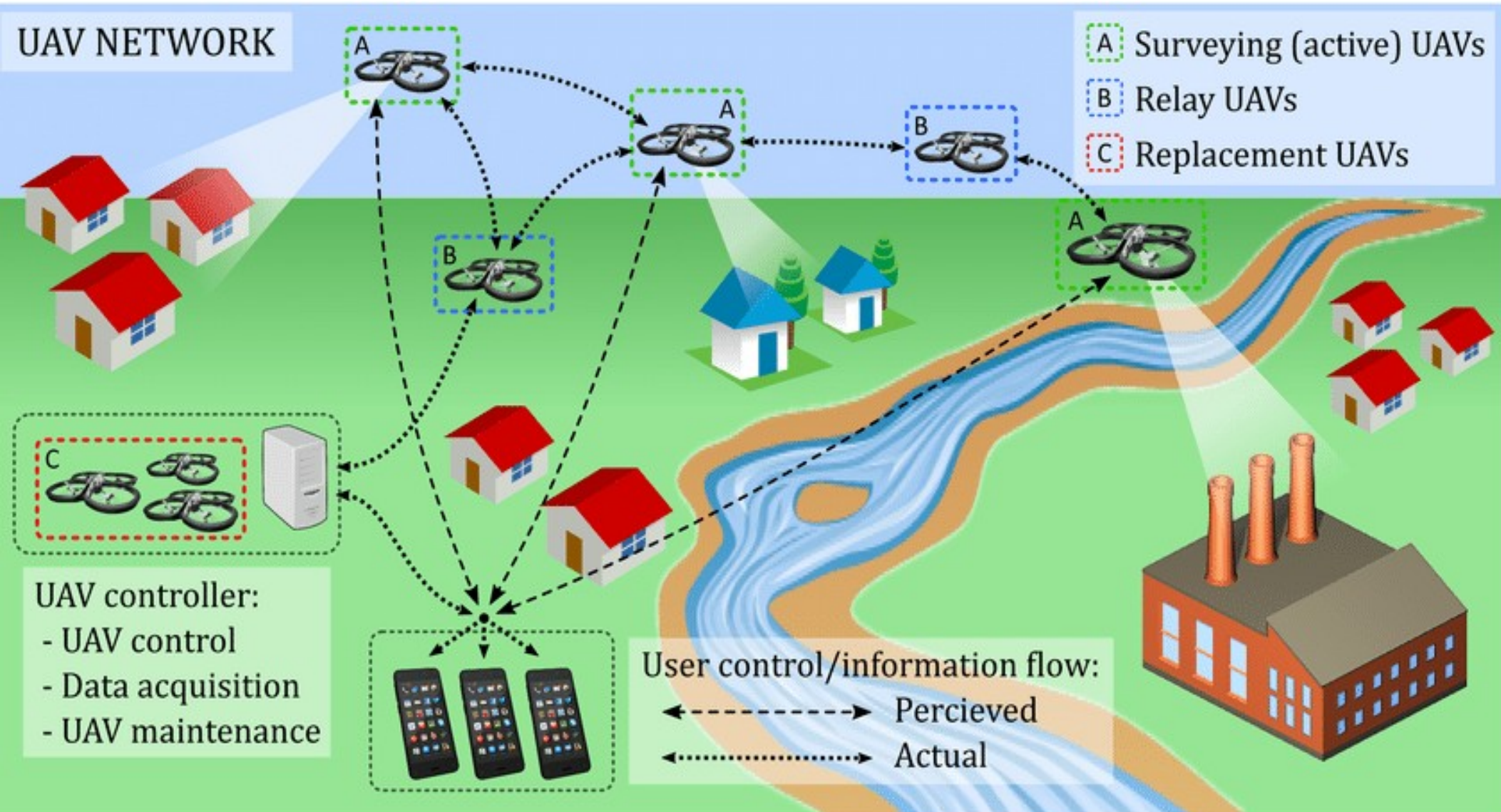


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Using Drones for Information Dissemination



Source: ERDELJ et al.: Drones, Smartphones and Sensors to Face Natural Disasters. https://www.researchgate.net/figure/UAV-network-used-for-surveillance-and-communication-support_fig1_325375622

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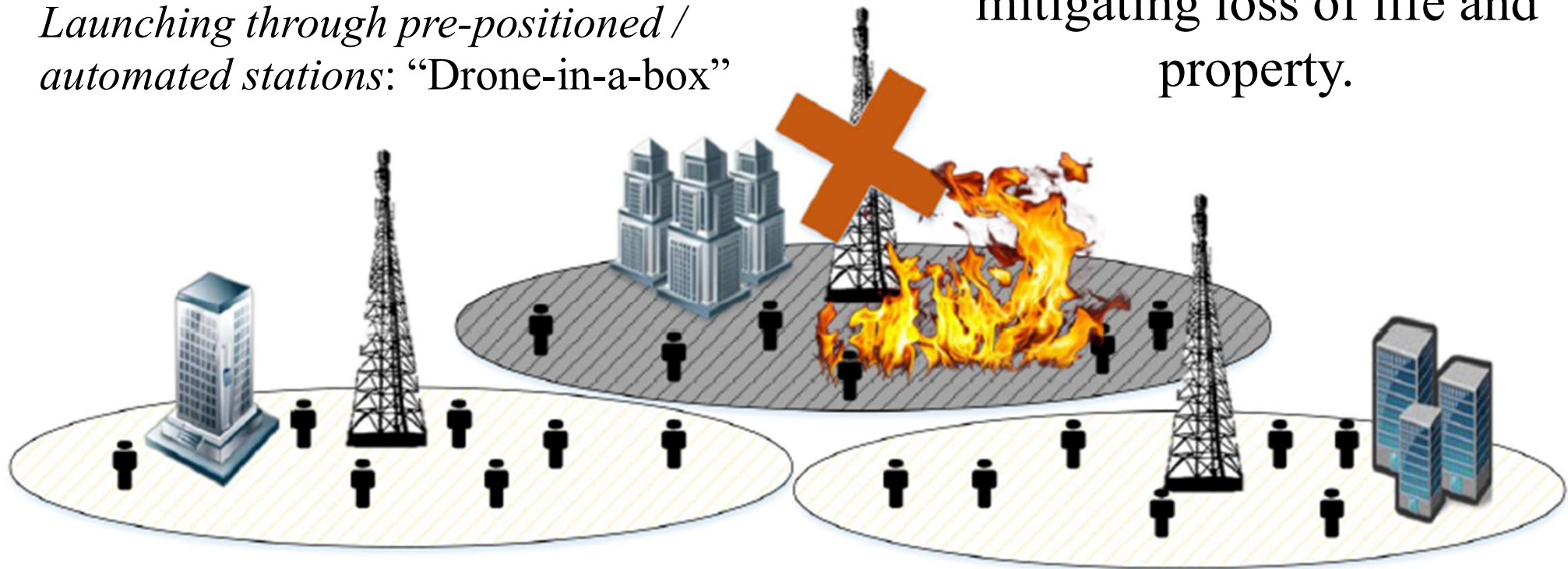
Drone Deployment: **Single-drone Approach**

Drone



- *Ad-hoc launching*
- *Launching through pre-positioned / automated stations: “Drone-in-a-box”*

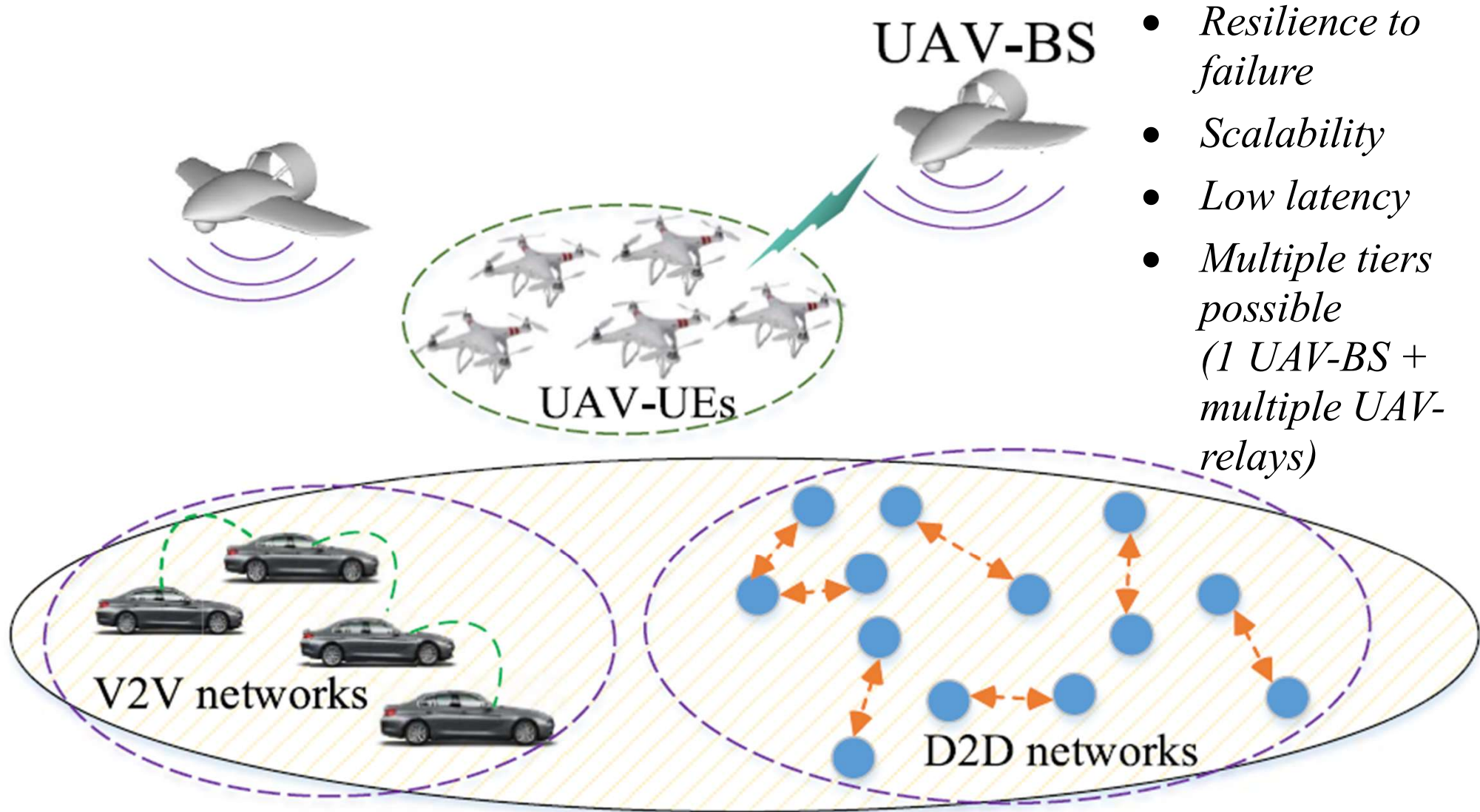
Timely and reliable communication is vital to coordinating rescue efforts, guiding civilians, and mitigating loss of life and property.



Source: MOZAFFARI et al.: A Tutorial on UAVs for Wireless Networks: Applications, Challenges, and Open Problems. <https://ieeexplore.ieee.org/document/8660516>

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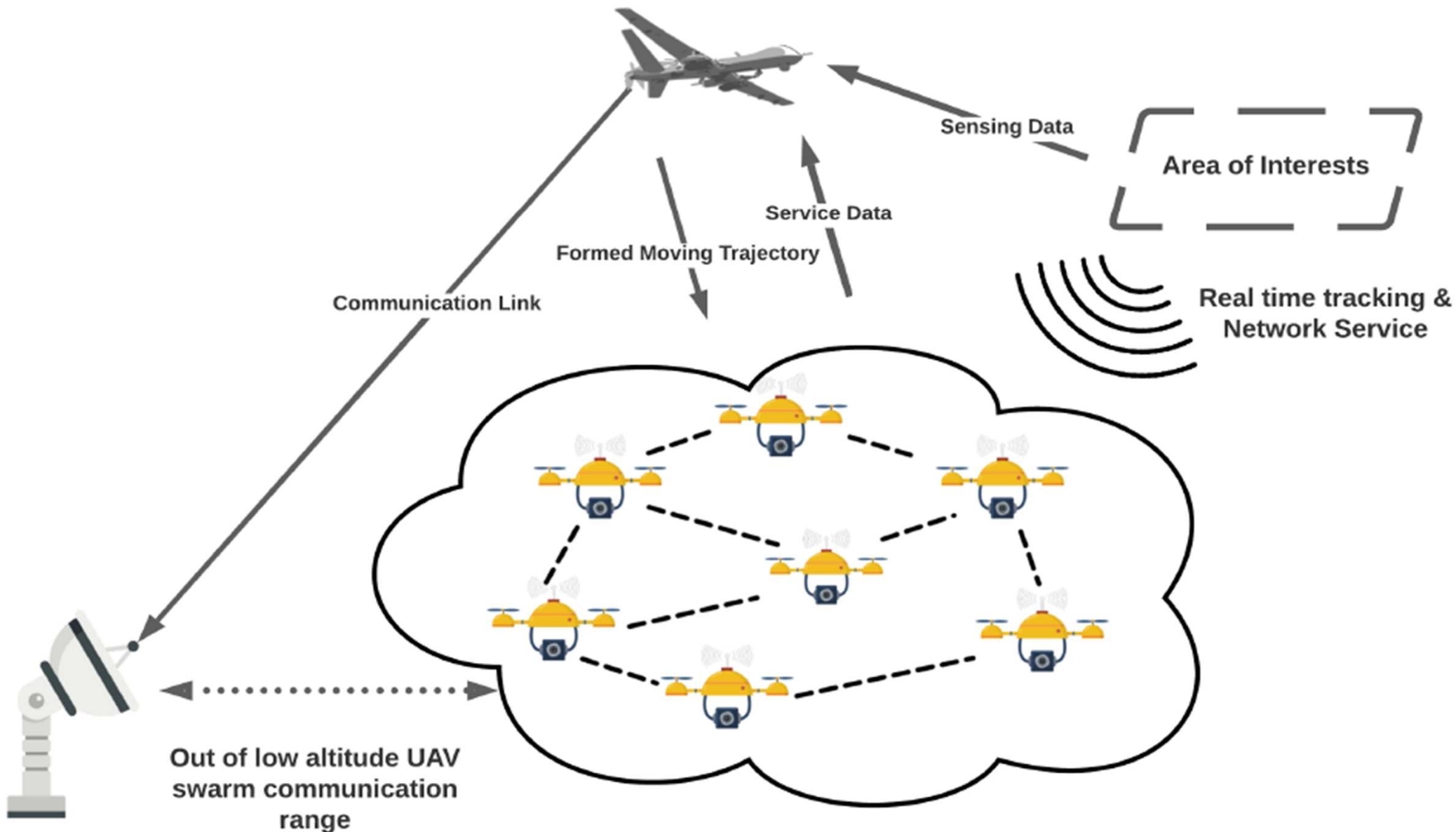
Drone Deployment: Clustered-drone Approach



Source: MOZAFFARI et al.: A Tutorial on UAVs for Wireless Networks: Applications, Challenges, and Open Problems. <https://ieeexplore.ieee.org/document/8660516>

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Drone Deployment: Hierarchical Swarm



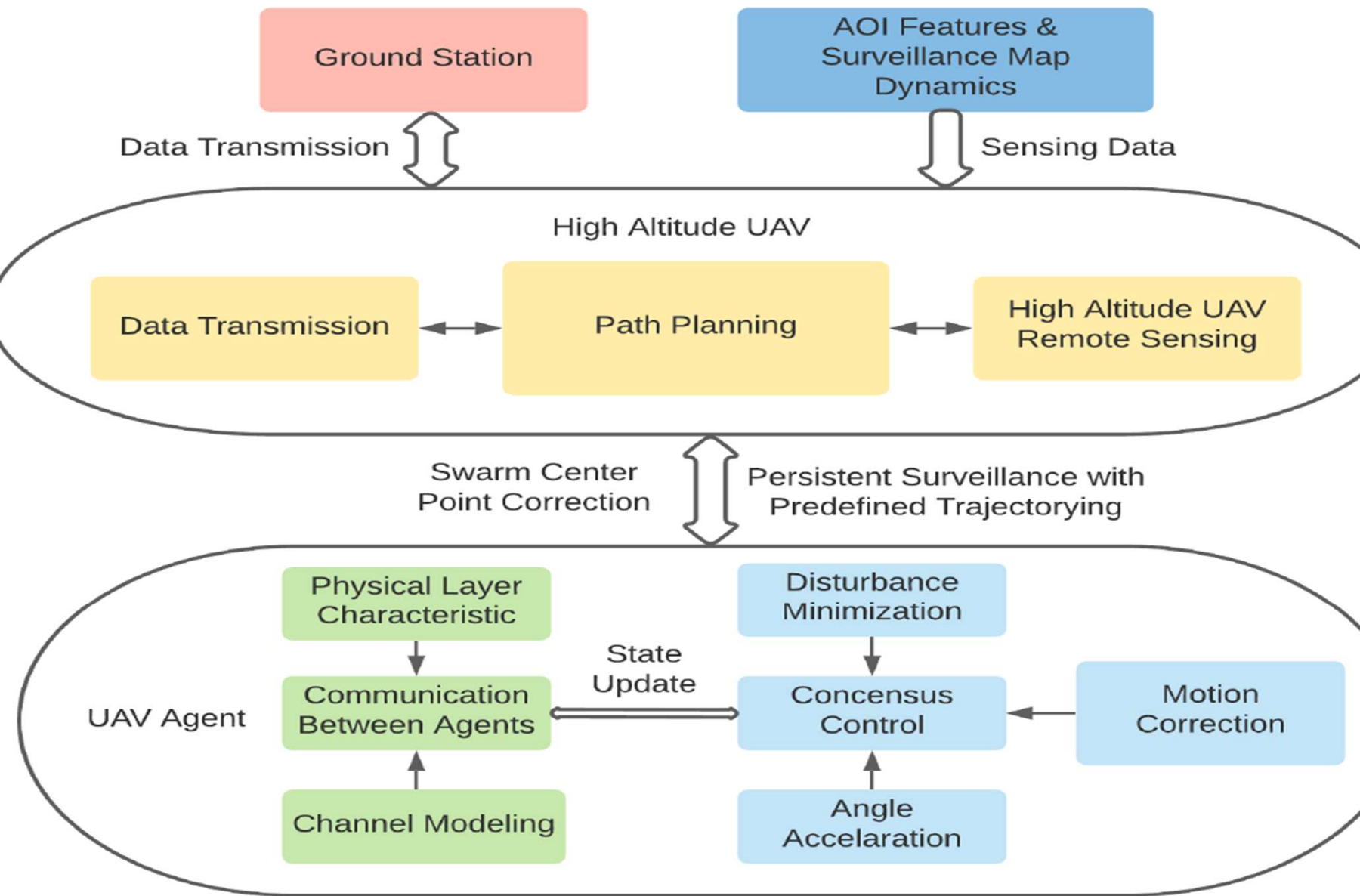
Source: XU et al.: Communication Aware UAV Swarm Surveillance Based on Hierarchical Architecture. <https://www.mdpi.com/2504-446X/5/2/33>

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Drone Deployment: **Swarm Operation**



Game-theory and ML algorithms, e.g., federated (deep) reinforcement learning (D/RL), are used for trajectory, coverage, cooperation, and interference management as to maximize comm. range and reliability.

Source: XU et al.: Communication Aware UAV Swarm Surveillance Based on Hierarchical Architecture. <https://www.mdpi.com/2504-4462/8/1/100>

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Drone Swarm Operation: **Scanning and Coverage**

- To maximize message reach, scanning strategies are used where drone fleets follow preassigned or dynamically computed paths—either grid-based, sweep-line, or region-dividing methods—to ensure comprehensive and overlapping area coverage
- Advanced region scanning algorithms consider:
 - The number and positions of drones
 - Topographical obstacles (mountains, buildings)
 - Predicted crowd/equipment locations and movement
 - Real-time connectivity assessment
- Simulation studies and real-life experiments demonstrate that ***collaborative*** drone missions markedly improve the speed and completeness of emergency communication, compared to isolated single-drone missions.

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AI-based Algorithms for Drone Operation

- Smart coordination algorithms for determination of optimal flight paths, dynamic task allocation, and resource management amidst evolving conditions.
 - Iterative Scheduling Algorithm of Trajectory and Resource (ISATR)
 - Particle swarm optimization (PSO) algorithm as a trajectory solution, and a block coordinate descent-based method for task offloading and resource allocation.
- DRL algorithms to enable drones to learn from experience and adjust their decision-making in real-time to navigate complex environments and optimize connectivity for tasks.
 - ✓ AD3QN, combined with an attention mechanism, simulates and adapts to realistic ground user distributions, A2G communication models, and electromagnetic interferences.
- ML models and LLM to help interpret vast amounts of data, quickly identify potential targets, and associate relevant knowledge to support the decision-making process.

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Future Trends in Drone-based Emergency Communication (1)

- Towards Multi-Layered, Intelligent Networks
 - Development of fully integrated *Space-Air-Ground Integrated Networks (SAGINs)*, where drones operate as essential links within dynamic, distributed communication architectures for seamless disaster response.
 - Incorporation of *6G technologies*, enabling higher data rates, lower latency, and *advanced AI/ML-driven autonomy* for deployment, path planning, and adaptive resource allocation.
- Autonomous and AI-Driven Drone Swarms
 - *Proliferation of AI-powered, collaborative drone swarms* capable of self-organizing, negotiating dynamic coverage, and optimizing both communication and data collection roles.
 - *Advanced (multi-agent) DRL* for on-the-fly drone adaptation to evolving disaster parameters.
- Advanced User Interfaces and Personalization
 - Utilization of *context-aware communication*, capable of targeting user clusters with personalized instructions, e.g., for evacuation, potentially integrating with wearable or medical devices.

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Future Trends in Drone-based Emergency Communication (2)

- Enhanced Security, Resilience, and Regulatory Integration
 - Continued *evolution of anti-jamming, encryption, and spectrum-management* technologies to protect both the command and message channels from malicious interference or overload.
 - *Standardization and regulatory harmonization* across national and international jurisdictions to ensure safe, controlled, and effective emergency drone operations. Future frameworks will likely include rapid national/international SWAT approval mechanisms, cross-border disaster cooperation protocols, and open interfaces for first-responder networks.
- Deep Multi-Modal Integration
 - *Tightly woven into smart infrastructures*: detecting disaster conditions via onboard sensors, autonomously launching, selecting the best media (text/image/audio/video), and feeding live data back to AI-powered situation rooms for comprehensive, closed-loop emergency management.
 - Broader adoption of cooperative drone–ground vehicle (GV) communication systems for synergistic, multi-modal disaster response — integrating ground sensors, human responders, and aerial fleets for holistic resource optimization.

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Human-in-the-Loop Operational Model

- AI as decision-support, not decision-maker
 - AI generates recommendations, not final decisions!
- Human oversight in high-stakes decisions
 - Human validation for high-impact actions
- Explainable AI (XAI) for trust and accountability
 - Training and trust-building
- Clear accountability frameworks
 - Feedback loops for continuous AI model improvement

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Challenges and Risks: **Ethics, Trust, and Security**

- Data quality, availability, minimization, purpose limitation, privacy (GDPR)
- Algorithmic bias and fairness in AI models
- Overreliance on automation
- Explainability, trust, transparency, and auditability of AI
- Unequal access to AI technologies
- AI pipeline robustness
- Cybersecurity threats

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Conclusions (1)

- AI transforms crisis management across all phases
 - Can significantly enhance crisis management by enabling predictive and effective operation
- AI can provide greatest value in speed, prediction, and coordination
 - Underlying system architecture must support real-time and cross-domain data
- Responsible usage of AI
 - Human oversight is mandatory in high-stakes decisions
- Trust, ethics, and security at system level
 - Systems must be human-centered and AI-augmented

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Conclusions (2)

- Governance & policy needs
 - Standards for AI in emergencies
 - International data-sharing agreements
 - Certification for AI-based tools
 - Human-in-the-loop requirements
- Future directions
 - AI-driven digital twins of cities
 - Fully autonomous emergency drones
 - Global AI disaster-prediction networks
 - Integration with 6G and edge computing
 - Explainable AI (XAI) for crisis management

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"ПРОГРАМА ЗА ОБРАЗОВАНИЕ"



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Thank you

Questions & comments ?

*“AI-driven Digital Technologies
for Crisis Management”*

A keynote talk of Prof. Ivan Ganchev

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