Control and spreading processes in multilayer networks

There is a **great interest in controlling spreading processes in multilayer networks, as this has great potential to make a significant impact on tackling critical societal challenges**, such as: **controlling and containing the spread of diseases** (e.g., COVID-19); influencing and **stopping the spread of extremism behaviour**; **inhibiting the spread of fake news**; **evaluating the influence of state control mechanism on financial networks**; or **controlling advertisement campaigns** (viral marketing, word of mouth), **political campaigns** (e.g. to assure that politician believes and opinions reach as many people as possible before the fixed deadline, i.e. voting day) or **social campaigns** (e.g. spreading awareness about pollution, waste sorting, vaccination, healthy lifestyle, etc.). Due to the heterogeneous nature of multilayer networks (networks where we can model many relations between nodes at the same time) through which the dynamical processes progress and their non-linear character, neither the network dynamics nor the dynamic processes over these structures can be analytically described. This poses severe constraints on the controllability of spreading processes. To address these issues, there is an **urgent need for extensive research into the multilayer networks' controllability** and suitable control mechanisms that would enable to direct the evolution of spreading processes in the desired way.

Fortunately, now, for the first time in human history, **we have the possibility to process big network data about the variety of interactions and activities of millions of individuals** that can be represented as a multilayer network. Not only we can analyse the dynamics of such structures but also spreading processes on those complex networks, including disease spread, opinion formation or fake news propagation. They represent an increasingly important resource in the process of understanding the behaviour of individuals, groups and whole communities. However, **there is no coherent and comprehensive approach to analyse (i) how the spreading processes in those multilayer networks look like, (ii) how we can influence and (iii) control those processes.** All three components are crucial to advance our understanding of continuously changing people's behaviour and propose mechanisms that help to change this behaviour if desired or necessary.

Dynamic processes over networks and their evolution are usually analysed by building models of the process that happens over very simple models. However, these do not reflect the complex nature of real-world multilayer networks and related processes with high enough accuracy for their effective control. Building on the previous related research the proposed transformative route forward to overcome the limitations of existing techniques for control of spreading processes is, therefore, in developing novel high accuracy data-driven complex network simulation models with the ability to accurately model and take into account the inherent dynamics of processes taking place in multilayer networks as well as the dynamic behaviour induced by the applied, proposed control mechanisms.

The main drive of this project is to understand the mechanisms behind spreading processes in real multilayer networks and use this knowledge to influence and control them. Thus, the main goal is to build a robust and adaptive framework that will address the following objectives:

1. To develop and evaluate methods for influencing spreading processes in multilayer networks
2. To develop control mechanisms of the multilayer network structure
3. To develop and evaluate methods for spreading processes control in multilayer networks
4. To evaluate proposed solutions on real multilayer networks

These objectives will be addressed within four Work Packages: **WP1** Influencing spreading processes in multilayer networks; **WP2** Controllability and control in multilayer networks; **WP3** Control of spreading processes in multilayer networks; and **WP4** Data acquisition, use cases, and results exploitation) executed over 36 months in collaboration with international partners from Australia, USA and Sweden.